

STATUS OF SNOW LEOPARD IN HIMACHAL PRADESH

2025



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CITATION INFORMATION

Anon. 2025. Status of snow leopard in
Himachal Pradesh, 2025.

Wildlife Wing - Himachal Pradesh Forest Department,
Government of Himachal Pradesh, Shimla.

COVER PHOTO BY

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Foreword



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The state of Himachal Pradesh, located in the northwestern Himalayas, is known for its unique geography and rich ecological diversity. The trans- Himalayan region of the state, marked by extreme cold, low precipitation, and rugged terrain, is a global biodiversity hotspot that supports a variety of species that are specially adapted to these extreme environments.

Among the most notable inhabitants of this region is the state animal - Snow Leopard, locally known as *Shen/Shan* and often referred to as the “Ghost of the Mountain.” This elusive predator is perfectly suited to the cold, rugged terrain and plays a vital role in maintaining ecological harmony of these high-altitude ecosystems. Along with the Snow Leopard, other species such as the Bharal (Blue sheep) and Ibex are key to the biodiversity of the area, contributing to the overall health of the ecosystem and the food chain. Himachal Pradesh has long been committed to wildlife conservation. The state’s efforts to protect these species and their habitats have led to significant advances in Snow Leopard Population Assessments, which are crucial for understanding the distribution of the species and devising effective conservation strategies. In 2021, the state released its first comprehensive report on Snow Leopard population survey, marking India’s first state-wide assessment of the species.

Building on this, the second round of Snow Leopard Population Assessments, conducted

by the Wildlife Wing of Himachal Pradesh Forest Department in collaboration with the Nature Conservation Foundation during 2024-25, marks a significant step forward. This round, which was completed in just one year, contrasts with the previous round that took over three years to complete. Over a challenging nine-month field period, the survey teams covered 26,000 km² of Snow Leopard habitat, providing valuable insights into the current status of the species and laying the groundwork for more focused and effective conservation management.

The camera trapping efforts not only captured data on Snow Leopards but also revealed other significant discoveries, such as the presence of the Pallas’s cat in Kinnaur, a species that had never been officially recorded before, and the Woolly Flying Squirrel, whose occurrence in the state was unknown for several decades. These findings reinforce my belief that much remains to be discovered about the trans-Himalayan ecosystems, underscoring the need for continued conservation efforts in this region.

This effort of population assessment would have not been possible without the support of local teams and communities. The local community members, well-versed with the terrain guided the camera trapping effort to fruition. Their contributions have been vital to the success of this project and emphasizes the role local communities play in wildlife conservation.

This remarkable achievement in Snow Leopard Population Assessment reflects Himachal Pradesh’s ongoing commitment to preserving its unique high-altitude ecosystems and the iconic Snow Leopards that inhabit them. I extend my heartfelt congratulations to all the officers of the Wildlife Wing HPFD for their unwavering commitment and tireless efforts in ensuring the success of this crucial project.

Executive Summary



Kesang Chunit

The snow leopard (*Panthera uncia*) is a Vulnerable species distributed across the South and Central Asian high mountain ranges, and is considered a flagship species for the conservation of Asia's high-altitude ecosystems. Reliable data on its distribution and population trends are essential for effective conservation planning. Monitoring trends in snow leopard population is critical to assess species status, the factors affecting its population, and evaluating the impact of conservation efforts. As an apex predator, snow leopard has considerable impact on the ecology of the alpine and subalpine ecosystem of upper Himalaya. Additionally, it holds cultural and regional significance as the state animal of Himachal Pradesh.

The 12 snow leopard range countries have jointly initiated an effort to conduct the Population Assessment of the World's Snow Leopards (PAWS). Recognizing the importance of understanding the populations and distribution of snow leopards across India, the Government of India launched India's PAWS effort, referred to as the "Snow Leopard Population Assessment of India (SPAI)". Himachal Pradesh was the pioneering state in conducting this activity, being the first to start it in 2017 and the first to conclude it in 2021. In late 2023 into 2024, nearly five years on from the first assessment of the snow leopard population in Himachal Pradesh, we aimed to repeat the population estimation exercise for a second time. This helped us understand how their population has changed since the first round

Reliable data on snow leopard distribution and population trends are essential for effective conservation planning.

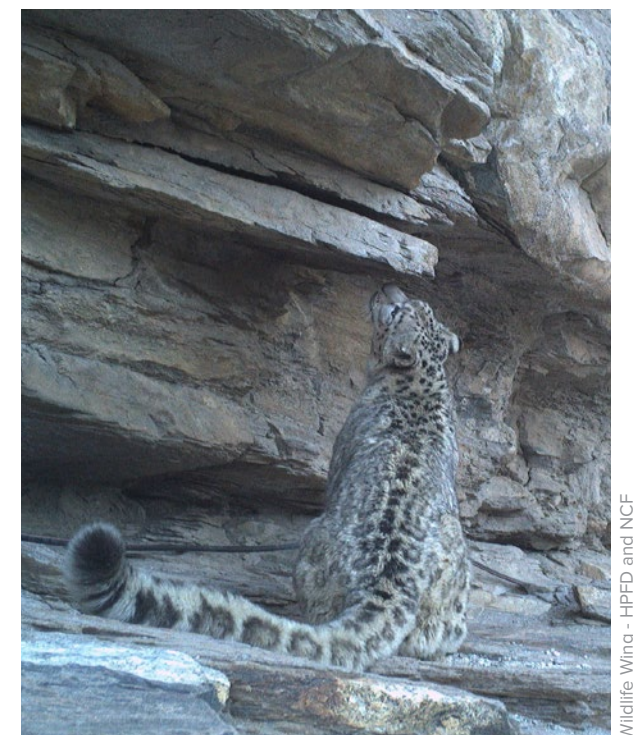
of estimation. Himachal Pradesh has become the first state/union territory to do so. We also aimed to reduce the time taken to conduct this exercise, which was previously three years, to one year. This was to ensure robust and cost-effective surveys into the future. This is particularly important as this can serve as a blueprint for all regions with snow leopards across India to continually monitor their populations. This work was done by Wildlife Wing - Himachal Pradesh Forest Department in collaboration with Nature Conservation Foundation and various members of the local community across Himachal Pradesh.

We used scientifically robust techniques that align with the protocols prescribed by the Ministry of Environment, Forest and Climate Change under Snow Leopard Population Assessment in India (SPAI). This report provides the final results obtained from this exercise. Listed below is a summary of the main results obtained for this project:

1. This project is the second systematic effort at a large regional scale to estimate snow leopard population over an area of 26,112 km² that utilised a stratified sampling design.

Given prior knowledge of the region, we divided the entire snow leopard habitat into two strata: high and low occupancy. Camera traps were then placed in both of these strata. By doing so, this study ensures no sampling bias is occurring, which is rather common in snow leopard population studies.

2. Camera trapping surveys representatively sampled both the high and low strata. Snow leopards were detected at all the sites suggesting that snow leopards are found in the entire snow leopard habitat in Himachal Pradesh – either as resident individuals of a population or as dispersing individuals navigating through these connecting habitats. We found cubs in several areas indicating the presence of breeding individuals.



Wildlife Wing - HPFD and NCF

3. We detected 44 individual snow leopards on 262 independent detections in this study. From this dataset of 44 individuals, we estimated that snow leopard population size is likely to be 83 (67-103) individuals. Across the low strata region (Lahaul-Pangi and GHNP) we estimate 24 (19-30) individuals and across the high strata region (USL and Kinnaur) we estimate 59 (48-73) individuals.

4. Snow leopard density ranged from 0.16 to 0.53 individuals per 100 km² in Himachal Pradesh. The trans-Himalayan regions of Upper Spiti Landscape (USL) and Pin recorded the highest densities of snow leopards, with the region of Kinnaur and Tabo being the subsequent regions with high densities. Lahaul-Pangi and GHNP were regions with lower densities. The derived density of snow leopards across Himachal

Pradesh was 0.35 (0.23-0.53) individuals per 100 km² with an estimated sigma of 5.2 (4.7-5.8) km.

5. We also provide trends in prey and snow leopard data for a period of five years from USL, between the first round of population estimation of snow leopards and now to see how populations are changing through time. We found fluctuations in wild ungulate abundance over the years, and the snow leopard density has largely remained constant. Snow leopard populations show a linear relationship with wild prey populations.

6. We leveraged detections of other mammals found in the same landscape to estimate their distributions using an ensemble modeling approach. Refined distribution maps were obtained for key prey species like blue sheep (*Pseudois nayaur*), Himalayan ibex

(*Capra sibirica*) and musk deer (*Moschus leucogaster*). Distributions were also refined for other mammals like the Himalayan wolf (*Canis lupus*), brown bear (*Ursus arctos*), common leopard (*Panthera pardus*), red fox (*Vulpes vulpes*), stone marten (*Martes foina*), mountain weasel (*Mustela altaica*) and yellow-throated marten (*Mustela flavigula*).

7. The entire camera trapping exercise was led by 23 people, including 11 women, across Himachal Pradesh's snow leopard landscapes. They were adequately supported by NCF researchers, frontline staff of HPFD and other villagers. To improve local capacity, 20 staff members of the Spiti Wildlife Division, including the Deputy Conservator of Forests (DCF), Kaza, were provided with a detailed understanding of the Snow Leopard Population Assessment of India (SPAI) guidelines and data collection protocols for this exercise. They were apprised about the workflow and data processing that is followed by fieldwork. Without the meaningful involvement of these local champions, it would not have been possible to shorten the survey time from three years in the first round to a year in this round, while maintaining the robustness of these methods.

8. Our results suggest an increase in the population of snow leopards from the first population estimation exercise which estimated 51 (44-73) individuals. This increase in the estimate needs to be interpreted with some considerations. These are that i) the confidence intervals between the first and second round of estimation overlap, ii) sigma (the movement parameter) markedly reduced during the second round of estimation, iii) minimum counts of individuals were similar between the two surveys, iv) the survey time

was shortened from three years to one, and v) having done this exercise once before, it is likely that the team was better equipped and trained in conducting the work this time around. This could have led to improved and more voluminous data, also influencing the shape of the detection functions.

9. This project is a scientifically robust and repeatable assessment of snow leopard populations in Himachal Pradesh, making it the first state in India to conduct such a comprehensive survey twice. This sets a precedent for other states and union territories to do the same and continually monitor snow leopard populations into the future. To ensure the long-term conservation of snow leopards and their habitats, it is essential to continue periodic monitoring of snow leopard populations, with annual assessments of both snow leopards and their prey in key sites like Spiti, Lahaul-Pangi and Kinnaur. Larger scale assessments such as across Himachal Pradesh can be done periodically - perhaps once every three-five years. We also need concerted efforts to understand the implications of possible expansion of common leopard into snow leopard territories and threats like feral dogs to snow leopard populations.



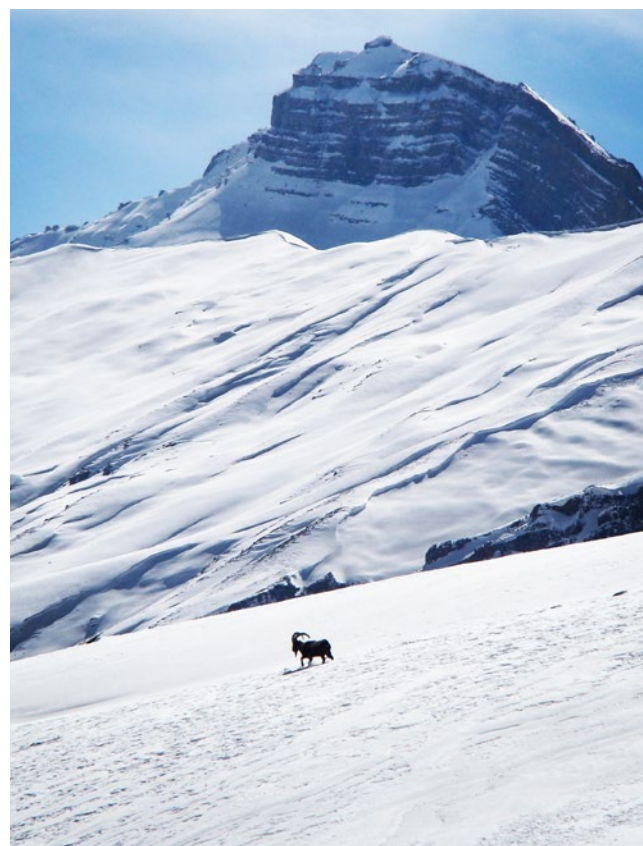
Udayan Rao Pawar

कार्यकारी सारांश

दक्षिण और मध्य एशियाई उच्च पर्वत श्रृंखलाओं में पाया जाने वाला हिम तेंदुआ (पैंथेरा अनसिया) तेंदुए की एक संकटग्रस्त प्रजाति है। एशिया के उच्च-ऊँचाई वाले क्षेत्र के पारिस्थितिकीय संरक्षण के लिए इस प्रजाति को महत्वपूर्ण माना जाता है। इसके वितरण और जनसंख्या प्रवृत्तियों पर विश्वसनीय डेटा प्रभावी संरक्षण योजना के लिए आवश्यक है। इस तरह हिम तेंदुए की प्रजाति की स्थिति, इसकी आबादी को प्रभावित करने वाले कारक और संरक्षण प्रयासों के प्रभाव का आकलन करने के लिए इसकी आबादी का अध्ययन महत्वपूर्ण है। शिकारी पशु के रूप में, हिमालय के ऊँचे पहाड़ों की पारिस्थितिकीय पर, हिम तेंदुए का बहुत प्रभाव है। यह सांस्कृतिक और क्षेत्रीय रूप से भी महत्वपूर्ण है और हिमाचल प्रदेश का राज्य पशु भी है।

हिम तेंदुआ क्षेत्र के १२ देशों ने संयुक्त रूप से विश्व के हिम तेंदुओं की जनसंख्या आकलन- पॉपुलेशन असेसमेंट ऑफ़ वर्ल्ड्स स्नो लेओपर्ड्स (PAWS)- करने का प्रयास शुरू किया है। भारत भर में हिम तेंदुओं की आबादी और वितरण को समझने के महत्व को समझते हुए, भारत सरकार ने भारत के PAWS प्रयास की शुरुआत की, जिसे “स्नो लेपर्ड पॉपुलेशन असेसमेंट ऑफ़ इंडिया (SPAII)” कहा जाता है। हिमाचल प्रदेश इस गतिविधि को संचालित करने वाला अग्रणी राज्य था, जिसने २०१७ में इसे शुरू किया और २०२१ में इसे समाप्त करने वाला पहला राज्य बना। २०२३ के अंत से २०२४ की शुरुआत के बीच, राज्य में हिम तेंदुओं की आबादी के पहले आकलन के लगभग पाँच साल बाद, हमने हिम तेंदुए की अनुमानित जनसंख्या की गणना दोबारा करने का लक्ष्य रखा। इससे हमें यह समझने में मदद मिली कि पहले दौर के आकलन के बाद से उनकी आबादी में क्या बदलाव आया है। ऐसा करने वाला हिमाचल प्रदेश, पहला राज्य/केंद्र शासित प्रदेश बन गया है। हम, इस प्रक्रिया में लगने वाले समय को भी कम करने के उद्देश्य से चले

और जो काम पहले तीन साल में हुआ था, वह एक साल में करने में सफल रहे। भविष्य में मजबूत और लागत-प्रभावी सर्वेक्षण सुनिश्चित करने की दिशा में यह एक महत्वपूर्ण कदम था। यह विशेष रूप से इसलिए भी महत्वपूर्ण है क्योंकि पूरे भारत में हिम तेंदुए वाले सभी क्षेत्रों के लिए उनकी आबादी की निरंतर निगरानी करने के लिए यह एक रूपरेखा के रूप में काम कर सकता है। यह परियोजना हिमाचल प्रदेश वन विभाग के वन्य जीव प्रभाग द्वारा नेचर कंजर्वेशन फाउंडेशन और पूरे हिमाचल प्रदेश में स्थानीय समुदाय के विभिन्न सदस्यों के सहयोग से किया गया है।



Kulbhushansingh Suryawanshi



Tanzin Tsewang

इस परियोजना में इस्तेमाल की गई तकनीकें वैज्ञानिक रूप से मजबूत हैं और भारत में हिम तेंदुओं की जनसंख्या आकलन (SPAII) के लिए पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय (MoEFCC) द्वारा निर्धारित प्रोटोकॉल के अनुरूप हैं। यह रिपोर्ट इस पूरी प्रक्रिया से प्राप्त हुए अंतिम परिणामों को प्रस्तुत करती है। इस परियोजना के मुख्य परिणामों का सारांश नीचे दिया गया है:

१. २६,११२ वर्ग कि.मी. के क्षेत्र में हिम तेंदुओं की आबादी की अनुमानित गणना का इतने विशाल क्षेत्रीय स्तर पर किया गया यह दूसरा व्यवस्थित प्रयास है, जिसमें स्ट्रेटिफ़ाइड सैंपलिंग डिज़ाइन का उपयोग किया गया है। क्षेत्र के पूर्व ज्ञान को ध्यान में रखते हुए, हमने हिम तेंदुए के संपूर्ण प्राकृतिक वास को दो स्तरों में विभाजित किया: उच्च अधिभोग क्षेत्र और निम्न अधिभोग क्षेत्र। फिर इन दोनों क्षेत्रों में कैमरा ट्रैप लगाए गए। इस से यह सुनिश्चित किया गया कि इस अध्ययन के लिए किसी पूर्व अध्ययन के नमूने के प्रति पूर्वाग्रह नहीं रखा गया है, जो हिम तेंदुओं की आबादी के अध्ययन में आम बात है।

२. कैमरा ट्रैपिंग सर्वेक्षणों ने उच्च और निम्न दोनों स्तरों का प्रतिनिधित्वात्मक रूप से नमूना लिया। सभी स्थलों पर हिम तेंदुए पाए गए, जिससे पता चलता है कि राज्य के सभी हिम तेंदुआ पर्यावासों में वे मौजूद हैं – ये या तो अपनी किसी आबादी का हिस्सा हैं, या फिर ये आपस में जुड़े पर्यावासों में आते-जाते रहते हैं। हमें कई स्थलों पर शावक मिले, जो प्रजनन करने वाले तेंदुओं की उपस्थिति का संकेत देते हैं।

३. इस अध्ययन में चिह्नित २६२ स्वतंत्र अवसरों पर ४४ हिम तेंदुओं का पता लगा। गणना में ४४ की संख्या के इस आंकड़े से, हमने अनुमान लगाया है कि हिम तेंदुओं की आबादी का आकार ८३ (६७ से १०३ के बीच) होने की संभावना है। निचले स्तर के क्षेत्र (लाहौल-पांगी और जीएचएनपी) में हमारी अनुमानित संख्या २४ (१९ और ३० के बीच) है और उच्च स्तर के क्षेत्र (स्पीति और किन्नौर) में ५९ (४८ और ७३ के बीच) है।

४. हिमाचल प्रदेश में हिम तेंदुओं का घनत्व ०.१६ से ०.५३ प्रति १०० वर्ग किमी पाया गया। ऊपरी स्पीति लैंडस्केप (यूएसएल) और पिन घाटी के ट्रांस-हिमालयी क्षेत्रों में हिम तेंदुओं का सबसे अधिक घनत्व दर्ज किया गया, इसके बाद किन्नौर और

ताबो तेंदुओं के उच्च घनत्व वाले क्षेत्र हैं। लाहौल-पांगी और जीएचएनपी कम घनत्व वाले क्षेत्र हैं। हिमाचल प्रदेश में हिम तेंदुओं का व्युत्पन्न घनत्व ५.२ (४.७- ५.८ के बीच) किमी के अनुमानित सिग्मा के साथ ०.३५ (०.२३ से ०.५३ के बीच) हिम तेंदुआ प्रति १०० वर्ग किमी पाया गया।

५. हम यूएसएल (USL) में पांच वर्ष की अवधि के बीच हिम तेंदुए और उसके शिकार के आंकड़ों का रुझान भी प्रदान करते हैं। यह हिम तेंदुओं की आबादी के अनुमान के पहले दौर और वर्तमान समय में आबादी में बदलाव को समझने में मददगार है। हमने पिछले कुछ वर्षों में जंगली खुर वाले जानवरों की उपलब्धता में काफी उतार-चढ़ाव पाया है, जबकि हिम तेंदुओं का घनत्व काफी हद तक स्थिर रहा है। हिम तेंदुए की आबादी उसके शिकार बनने वाले जीवों की आबादी से सीधा सम्बन्ध रखती है।
६. हमने लक्षित न की गई प्रजातियों के वितरण का अनुमान लगाने के लिए सह-अस्तित्व वाली अन्य प्रजातियों की कैमरा ट्रैप तस्वीरों से मिली उपस्थिति का लाभ उठाया, जिसके लिए एक एन्सेम्बल मॉडलिंग एप्रोच का उपयोग किया। भरल, हिमालयी

आइबेक्स और कस्तूरी मृग जैसी प्रमुख शिकार प्रजातियों की उपस्थिति के बेहतर मानचित्र प्राप्त किए गए। भेड़िया, भूरा भालू, सामान्य तेंदुआ, लाल लोमड़ी, स्टोन मार्टन, माउंटेन वीज़ल और येलो थ्रोटेड मार्टन जैसे अन्य स्तनधारी वन्यजीवों के वितरण को भी अधिक सटीक रूप से परिभाषित किया गया।

७. कैमरा ट्रैपिंग की पूरी कवायद का नेतृत्व हिमाचल प्रदेश के हिम तेंदुआ आवास क्षेत्र के २३ चयनित लोगों ने किया, जिसमें ११ महिलाएं भी थीं। उन्हें एनसीएफ (NCF) शोधकर्ताओं, हिमाचल प्रदेश वन विभाग के फ्रंटलाइन कर्मचारियों और अन्य ग्रामीणों द्वारा पर्याप्त सहयोग दिया गया। स्थानीय क्षमता को मजबूत करने के लिए, काजा के उप वन संरक्षक (डीसीएफ) सहित स्पीति वन्यजीव विभाग के २० कर्मचारियों को इस अभ्यास के लिए हिम तेंदुआ जनसंख्या आकलन - इंडिया (SPAI) के दिशा-निर्देशों और डेटा संग्रह प्रोटोकॉल की विस्तृत जानकारी प्रदान की गई। उन्हें फील्डवर्क के बाद की कार्यप्रणाली और डेटा प्रोसेसिंग की प्रक्रिया से अवगत कराया गया। इन स्थानीय चैंपियनों की सार्थक भागीदारी के बिना, प्रक्रिया की सटीकता को बनाए रखते हुए, पहले दौर में लगने वाले तीन साल के



Kaizang Gurmet



Dorje Angrup

समय को नए सर्वेक्षण के दौर में एक साल करना संभव नहीं होता।

- हमारे परिणाम प्रथम जनसंख्या आकलन अभ्यास से हिम तेंदुओं की जनसंख्या में वृद्धि की ओर इशारा करते हैं, जिसमें ५१ (४४ और ७३ के बीच) तेंदुओं का अनुमान लगाया गया था। अनुमान में वृद्धि की व्याख्या के कुछ आधार हैं, जिन्हें ध्यानपूर्वक समझा जाना चाहिए, जैसे कि १. पहले और दूसरे आकलन दौर के कॉन्फिडेंस इनटर्वल में अधिव्यापन है, २. सिग्मा (स्थान परिवर्तन की गतिविधि को ध्यान में रखना) अनुमान के दूसरे दौर के दौरान स्पष्ट रूप से कम हो गया, ३. दो सर्वेक्षणों के बीच तेंदुओं की न्यूनतम संख्या समान थी, ४. सर्वेक्षण का समय तीन साल से घटाकर एक साल कर दिया गया था, और ५. इस अभ्यास को एक बार पहले करने के बाद, इस बार टीम बेहतर ढंग से काम करने के लिए सुसज्जित और प्रशिक्षित थी। सम्भवतः इससे बेहतर और अधिक मात्रा में डाटा मिल सका, जो अध्ययन की प्रक्रिया को भी प्रभावित करता है।

यह परियोजना हिमाचल प्रदेश में हिम तेंदुओं की आबादी का

९. वैज्ञानिक रूप से सटीक और दोहराने योग्य आकलन है और इस तरह यह ऐसा व्यापक सर्वेक्षण दो बार करने वाला भारत का पहला राज्य बन गया है। यह अन्य राज्यों और केंद्र शासित प्रदेशों के लिए एक मिसाल कायम करता है, ताकि वे भी इसी तरह हिम तेंदुआ जनसंख्या की निरंतर निगरानी कर सकें। हिम तेंदुओं और उनके आवासों के दीर्घकालिक संरक्षण को सुनिश्चित करने के लिए, स्पीति, लाहौल-पांगी और किन्नौर जैसे प्रमुख स्थलों में हिम तेंदुओं और उनके शिकार दोनों का वार्षिक आकलन किया जाना चाहिए, जबकि हिमाचल प्रदेश जैसे बड़े क्षेत्रों में व्यापक आकलन हर तीन से पांच वर्षों में किया जा सकता है। इसके अतिरिक्त, हमें हिम तेंदुओं के क्षेत्रों में आम तेंदुओं के संभावित विस्तार और हिम तेंदुओं की आबादी के लिए आवारा कुत्तों जैसे खतरों को समझने के लिए कुछ ठोस प्रयासों की आवश्यकता है।

Introduction

In India, snow leopards *Panthera uncia* are found across Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. They are the state animal of Himachal Pradesh. Being a charismatic species that ranges over large areas, snow leopards are considered to be an umbrella and a flagship species for the conservation of the larger Himalayan habitat and the various species that inhabit it. This high altitude snow leopard habitat in India is a source of local and regional ecosystem services (Murali et al., 2017) which includes fresh water used by millions of people living downstream and in the plains, and sustains unique high-altitude cultures. Snow leopards are known to range widely and hence their conservation requires efforts on land well beyond protected area boundaries to promote coexistence with local communities (Ale & Mishra, 2018; Johansson et al., 2016).

However, the snow leopard faces various threats across its distributional range. Increasing large-scale development such as mining and ill-planned green energy projects are shrinking its fragile habitat (Heiner et al., 2024). Its livestock depredation behaviour can result in retaliatory killing by pastoral communities that it shares space with (Suryawanshi et al., 2013). Also, heightened climate change is further

Being a charismatic species that ranges over large areas, snow leopards are considered to be an umbrella and a flagship species for the conservation of the larger Himalayan habitat and the various species that inhabit it.

shrinking its high-altitude home (Forrest et al., 2012). In some areas, there might be an additional threat to snow leopards through direct poaching. Unregulated tourism and poor waste management are contributing to the rise of feral dog populations, posing further challenges to snow leopard conservation.

As a push towards effective snow leopard conservation, India has endorsed and played



a crucial role in the Global Snow Leopard Ecosystem Protection Program (GSLEP), which is a high level intergovernmental alliance of all 12 snow leopard range countries. These countries had jointly initiated an effort to conduct the Population Assessment of the World's Snow Leopards (PAWS) (Sharma et al., 2024; *The Bishkek Declaration, 2017*). Recognizing the importance of understanding the populations and distribution of snow leopards across India, the Government of India launched India's PAWS effort, referred to as the "Snow Leopard Population Assessment of India (SPAI)". The first round of SPAI was conducted between 2017-2023 which indicated a total of 718 snow leopards to be present in India (MOEFCC, 2023). Himachal Pradesh was the pioneering state in conducting this activity, being the first to start it in 2017 and the first to conclude it in 2021 (Anon., 2021). This was among the first projects to be completed successfully that has attempted an assessment of snow leopards at this scale. The techniques deployed for this were scientifically robust and aligned with the protocols prescribed by the Ministry of Environment, Forest and Climate Change under SPAI (MOEFCC, 2019).

In late 2023, nearly five years on from the first assessment of the snow leopard population (about seven years from the data collection for it) in Himachal Pradesh, we aimed to repeat the population estimation exercise for a second time. The objectives of this were to estimate the population of snow leopards in Himachal Pradesh for a second time, allowing us to understand how their population has changed since the first round of estimation. Himachal Pradesh has become the first state/union territory to do so. We also aimed to reduce the time taken to conduct this exercise

(previously three years) to ensure robust, cost-effective and more of such repeated surveys into the future. This is particularly important as this can serve as a blueprint for all regions with snow leopards across India to continually monitor their population. This is crucial in understanding how their populations are changing, what is the impact of conservation on their populations, and which areas might need specific conservation attention.

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Methods

The snow leopard landscape in Himachal Pradesh is shaped by valleys carved by major rivers such as the Sutlej, Chenab, Beas, and Parvati, along with their tributaries like the Baspa, Kugti, Ravi, Pare-chu, and Spiti. Large parts of this landscape are difficult to access given the breaks caused by the numerous rivers and streams. Snow leopards inhabit landscapes of diverse geology, starkly different climatic regimes, diverse vegetation and community structures.

Since snow leopard is an elusive species that occurs in low densities, studies generally tend to target smaller areas with relatively high densities. Estimating snow leopard populations only in small or high-density areas can overstate their numbers, creating biases when extended to

larger regions (Suryawanshi et al., 2019). To arrive at accurate estimates especially across large spatial scales, sampling must be representative and reflect the landscape's diversity. We used the techniques and protocols prescribed by the Ministry of Environment, Forest and Climate Change under SPAI to ensure robust study design (MOEFCC, 2019). The macro-level status of the snow leopard habitat in the state is now known from the first round of the occupancy surveys (Anon., 2021; Suryawanshi et al., 2021). High occupancy regions for snow leopards in Himachal Pradesh are Spiti and Kinnaur, whereas low occupancy regions are Lahaul, Chamba and parts of Kullu.



NCF

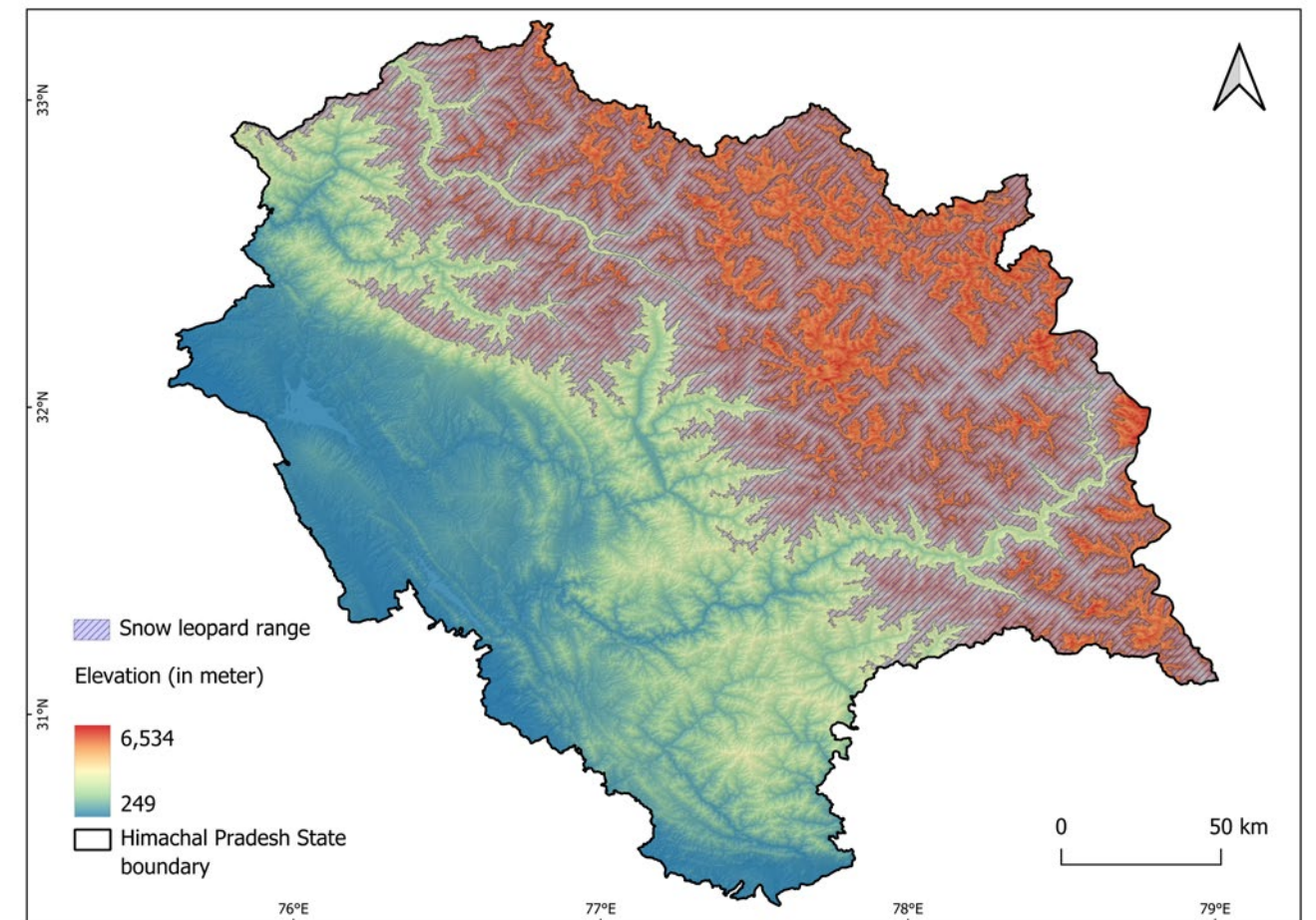


Figure 1: Snow leopard range in Himachal Pradesh

To arrive at accurate estimates especially across large spatial scales, sampling must be representative and reflect the landscape's diversity.

Micro - sampling design

For the second round, the goal was to sample large areas (>500 sq.km.) of potential snow leopard habitats across both the high and the

low strata, representatively. The habitat of the snow leopard largely spanned ranges along the main river valley and ranges along valleys of larger tributaries. Slopes on both banks of the rivers that were within the demarcated area were gridded into 4 x 4 km cells. We ensured at least one camera trap deployed per grid and at least two or more camera traps (Sollmann et al., 2012) within reported home range size estimates, that is 207 and 124 sq.km for male and female snow leopards, respectively (Johansson et al., 2016). It is smaller than the estimated home range size of snow leopards, thus allowing for the possibility of capture across multiple traps which enables robust estimation of the scale of movement in a spatially explicit analysis.

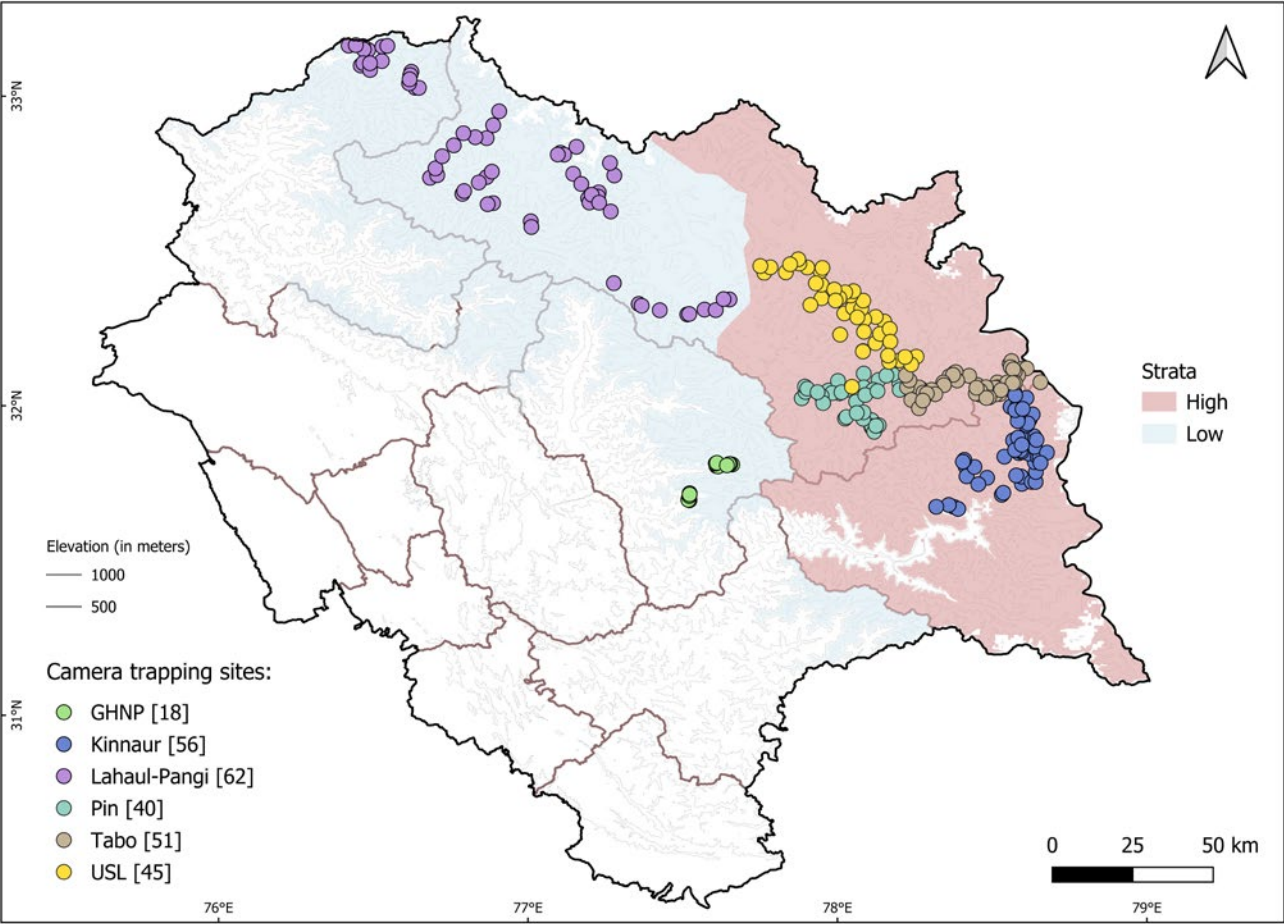


Figure 2: Camera trapping sites covering the two strata – high: Kinnaur, USL, Pin and Tabo; low: Lahaul-Pangi and GHNP

The camera-trap locations were selected to capture as many individuals as possible by multiple cameras, while optimising spatial coverage. Cameras were installed based on prevalence of snow leopard signs such as hair, scat, scrape or urine spray marks and suitable microhabitats to maximize detection within each cell. We covered the entire state of Himachal Pradesh in four bouts which covered six sites 1) Kinnaur 2) Spiti (split into Tabo, Pin and USL), 3) Lahaul-Pangi and 4) Great Himalayan National Park. We used Reconyx Hyperfire 2 and Reconyx HC500 cameras that were installed for 60 days, during which, cameras were checked once for battery condition and for replacement of memory cards (see Table 1 for camera-trapping effort for each site).

Cameras were installed based on prevalence of snow leopard signs such as hair, scat, scrape or urine spray marks and suitable microhabitats to maximize detection within each cell.

Table 1 - Effort of camera trapping survey across Himachal Pradesh

Name of Site	Strata	Estimated Area (km ²)	Monitoring Period	Number of camera traps deployed	Number of Occasions
Kinnaur	High	1229	March - May 2024	56	60
Tabo		862	June - early September 2024	51	60
Pin		754	June - early September 2024	39	60
USL		1191	June - early September 2024	45	60
Lahaul-Pangi	Low	5096	October - early December 2024	62	60
GHNP		256	September - November 2023	18	45

4 rounds of fieldwork spanning spring, summer, autumn-early winter; 271 camera traps deployed across the entire snow leopard habitat; 60 days in field for sampling

Image processing and data analysis

Upon retrieval of the cameras, all snow leopard images were tagged using the digiKam image management software (<https://www.digikam.org/>) and tags were read-out using the Camtrap R package (Niedballa et al., 2016). In the primary stage of tagging, all wildlife images were verified and tagged to the species level. In the second stage to minimise errors and ensure data quality we followed a two step process for individual identification. Errors in snow leopard image identification have been shown to bias estimates of density and population size (Johansson et al., 2020; Sharma et al., 2014). Following GSLEP guidelines and as done during the first round of population estimation, to minimise this bias, we conducted image identification and tagging in two stages – first identification stage followed by the review stage. In the first stage, two researchers independently identified snow leopards. Snow leopards were uniquely identified using rosette patterns from the face, limbs, rump,

shoulder, upper parts of the tail and cheeks. Unique individuals were only confirmed with at least three distinct patterns across three areas of the body. Attempt was to ensure two sided profiles for each unique individual - although in some cases enough evidence was available to attribute unique IDs using one side of the profile. Following this, in the second phase, two independent researchers reviewed all the individuals and especially those individuals that were captured only once. If there was insufficient evidence or single captures attributed as unique individuals, we reverted the image as ‘unidentified’ or in case of a misidentification we re-assigned the identification. If both independent reviewers agreed on the changes, then they were retained. Disagreements between the reviewers were resolved by a third reviewer. Information on the age structure and gender of snow leopards cannot be inferred from camera trapping data.

Snow leopards were uniquely identified using rosette patterns from the face, limbs, rump, shoulder, upper parts of the tail and cheeks. Unique individuals were only confirmed with at least distinct patterns across three areas of the body.



Charu Sharma



Tanzin Thuktan

SECR Analysis

We estimated the density and abundance of snow leopards for the state and at each site using maximum-likelihood based Spatially Explicit Capture-Recapture (SECR) models, with the secr 5.1.0 package in R (Efford et al., 2025; R Core Team, 2020). SECR is a form of hierarchical model that explicitly uses the spatial information of detections at the camera traps, accounting for the probability of capture relative to the animal's activity centre (Efford et al., 2009). We used a multi-session SECR model wherein sessions corresponded to the sampling sites (Kinnaur, Tabo, Pin, USL, Lahaul-Pangi and GHNP), where each session was assumed to have a closed population.

For estimating density, we used a model with density varying by session ($D \sim \text{session}$, $g_0 \sim 1$, $\sigma^2 \sim 1$), a hazard half-normal detection function, and a habitat mask with 36 km buffer and 1 km spacing, clipped to snow leopard habitats - regions above tree cover, typically at elevations higher than 3000 m but sometimes as low as 2000 m closer to river valleys. Abundance was estimated for the potential snow leopard habitat of 26,112 km² in the state. We calculated derived estimates of density and population size from the fitted model. Population size was estimated by multiplying the stratum area (low occupancy and high occupancy regions) with the density estimate for that stratum (Suryawanshi et al., 2021). Abundance calculation was done for each stratum, and the estimates and the variance terms were summed to get a population size estimate for the entire area.



Charu Sharma

Results

Our sampling resulted in 44 individual adult snow leopards identified from 262 independent detections across the six sites. At the level of the sites, our sampling from high occupancy stratum resulted in USL having 12 individual snow leopards from 90 detections, Tabo with 6 individual snow leopards from 46 detections, Pin with 8 individual snow leopards with 35 detections and Kinnaur having 9 individual snow leopards from 58 detections. From the low occupancy stratum, Lahaul-Pangi had 8 individual snow leopards from 32 detections, and GHNP had 1 individual snow leopard from 1 detection.

Our sampling resulted in 44 individual adult snow leopards identified from 262 independent detections across the six sites.

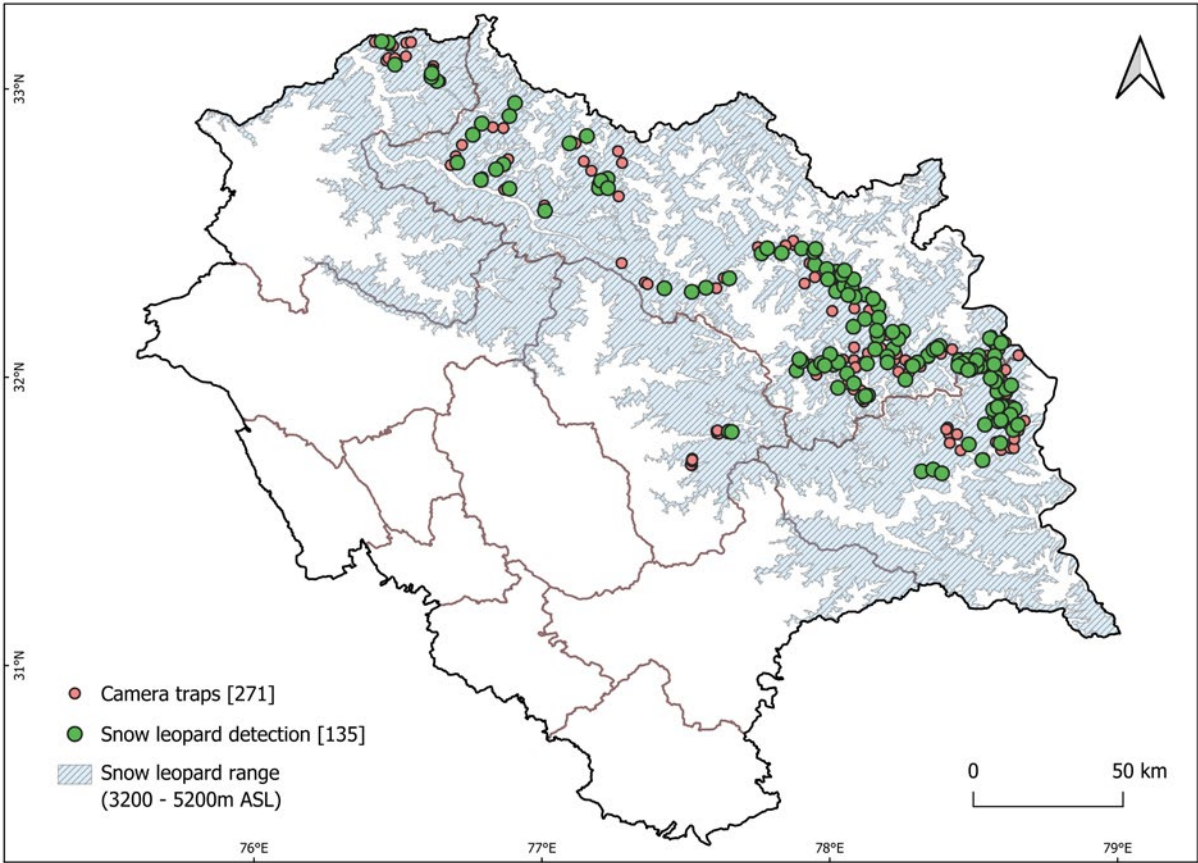


Figure 3: Snow leopard detections from camera traps across all sites

At the state-level, our SECR analysis resulted in the estimated snow leopard density of 0.35 (95% CI: 0.23 - 0.53) snow leopards per 100 km² and abundance of 83 (95%CI: 67 - 103) adult snow leopards in Himachal Pradesh. Density and abundance in the high occupancy strata were 0.46 (0.37 - 0.57) snow leopards per 100 km² and 59 (48 - 73) snow leopards. In the low occupancy strata, density and abundance were 0.18 (0.14 - 0.23) snow leopards per 100 km² and 24 (19 - 30) snow leopards.

At the site-level, USL had the highest snow leopard density of 0.53 (95% CI: 0.30 - 0.94)

snow leopards per 100 km², followed by Pin with a density of 0.51 (95%CI: 0.26 - 1.01) snow leopards per 100 km² and Kinnaur with density of 0.44 (95% CI: 0.23 - 0.84) snow leopards per 100 km². Tabo had an estimated density of 0.35 (95% CI: 0.16 - 0.77). Lahaul-Pangi had an estimated density of 0.18 (95% CI: 0.09 - 0.36) snow leopards per 100 km², and GHNP had the lowest estimated density of 0.16 (95% CI: 0.03 - 0.80) snow leopards per 100 km² (Table 2). The g0 was 0.028 (95% CI: 0.027 - 0.029), and sigma (indicator of movement) was estimated to be 5.2 (95% CI: 4.7 - 5.8) km.

Table 2. Details of camera trapping efforts across Himachal Pradesh

Name of Site	Estimated Area (km ²)	Number of camera traps deployed	Trap nights	No. of snow leopard detections	No. of individual snow leopards identified	Estimated snow leopard density per 100 km ² (95% CI)
Kinnaur	1229	56	3080	58	9	0.44 (0.23 - 0.84)
Tabo	862	51	2745	46	6	0.35 (0.16 - 0.77)
Pin	754	39	2156	35	8	0.51 (0.26 - 1.01)
USL	1191	45	2538	90	12	0.53 (0.30 - 0.94)
Lahaul-Pangi	5096	62	2753	32	8	0.18 (0.09 - 0.36)
GHNP	256	18	734	1	1	0.16 (0.03 - 0.80)

Total number of camera traps: 271; estimated area: 26,112 km²; total snow leopard detections: 262

Site Information

Kinnaur

Kinnaur, a high-altitude region of the state, is marked by the rugged mountains, precipitous valleys, and the three rivers, Sutlej, Baspa and Spiti. The landscape is a matrix of fruit orchards and the trans-Himalayan pastures. It experiences harsh winters, with most precipitation occurring as snow. Hangrang Valley, the second largest valley in Kinnaur, is primarily an arid alpine region. This valley lies adjacent to Spiti in the upper Kinnaur region and is situated near the Tibetan border on the northern and eastern sides of Himachal Pradesh. Temperatures range from 25°C in summer to as low as -35°C in winter.

Camera trapping was conducted in three areas of Kinnaur: the Lippha-Asrang region, Ropa Valley, and Hangrang Valley— from Khab bridge to Shalkhar-Thangkerma including the Upper Sutlej valley. The Lippha-Asrang region of Kinnaur is also part of a cold desert, known for its rich biodiversity, including alpine forests, rare wildlife, and the Asrang Wildlife Sanctuary.

We detected 9 snow leopard individuals from 58 detections from this site in our camera traps, and the estimated snow leopard density was 0.44 (95% CI: 0.23 - 0.84) per 100 km².



Charu Sharma



Charu Sharma

Tabo

The Tabo region is a trans-Himalayan region in the lower Spiti area of Himachal Pradesh. We covered areas on both the banks of the Spiti river in this region. This area extended from between Schilling and Hurling villages, centered around Tabo including Gue and Sumdo. The average altitude here is lower than USL (see below). We detected 6 snow leopard individuals from 46 detections and the estimated snow leopard density was 0.35 (95% CI: 0.16 - 0.77) per 100 km².

Pin

In Pin valley, the camera trapping area was situated in the catchment of the Pin River within the Pir Panjal range of the Himalayas. This included several key regions: the Ensa Nallah (stream) and its surroundings around and beyond Mudh village, the area near

Sagnam village, and the core region of the Pin Valley National Park, located west of Sagnam village. The Geychang-Thango area and its connected side valleys were also part of the survey. We detected 8 snow leopard individuals from 35 detections and the estimated snow leopard density was 0.51 (95% CI: 0.26 - 1.01) per 100 km².

USL

Nestled in the Indian trans-Himalayas and ranging across an altitude of 3500-6700 m, the administrative unit of Spiti covers an area of 7000 km² and has a predominantly rugged terrain. Temperatures vary from -40°C in peak winter to 30°C in summer and the vegetation may broadly be classified as 'dry alpine steppe'. Hosting unique biodiversity, the landscape is a critical habitat for various wildlife species. This



Shahid Hameed

encompassed both banks of the Spiti river from the region of Lossar village, including parts of the Kibber Wildlife Sanctuary, downstream to Demul village.

We detected 12 individual snow leopards across 90 detections with an estimated density of 0.53 (95% CI: 0.30 - 0.94) per 100 km².

Lahaul-Pangi

The Lahaul valley falls under the Lahaul and Spiti district, with a total area of about 6244 km² and an altitude ranging from 2400 to 6517 m. The climate varies from dry temperate to alpine. Temperature ranges from -19°C to 32°C with snowfall being the major form of precipitation. The vegetation is mainly of temperate, subalpine and alpine types. The area is divided into four valleys: Miyar, Chandra, Bhaga and Chandra-Bhaga, which were also our camera placement sites. In Lahaul the main river catchments where

the cameras were placed were Chandra, Bhaga and Miyar-Thirot, centered around Keylong.

The Pangi valley is located in the north western most part of Himachal Pradesh in Chamba district. It lies at the confluence of the greater and trans-Himalaya and forms a critical corridor for high-altitude wildlife. It is characterized by rugged topography, deep valleys, and high-altitude alpine zones. Pangi valley is subdivided into four major sub-valleys: Hudan, Sural, Saichu, and Parmar. It is drained by the Chandrabhaga River. The camera trapping for this area covered the 4 sub-valleys (locally known as Bhatoris) including Sechu-Tuan Nala Wildlife Sanctuary.

We detected a total of 8 individual snow leopards on 32 detections from this region, and the estimated snow leopard density was 0.18 (95% CI: 0.09 - 0.36) per 100 km².

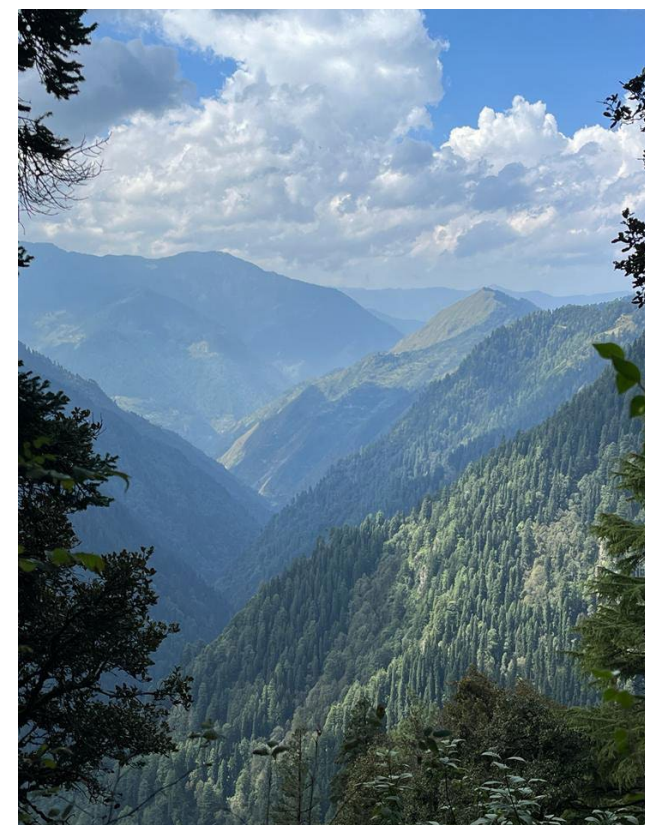


Kalzang Gurmet

Great Himalayan National Park (GHNP)

The Great Himalayan National Park, located in Himachal Pradesh, is a UNESCO World Heritage Site known for its pristine alpine and subalpine ecosystems. The region is spread across four valleys, Tirthan, Parvati, Sainj and Jiwa nala. The vegetation here comprises diverse ecological zones, including alpine scrub, alpine meadows-pastures, temperate broadleaved forests, temperate conifer forests, and mixed broadleaved-conifer forests (Nandy et al., 2015). Camera traps were placed in two valleys, Sainj valley till Rakti and the Tirthan valley till Kubri Top.

We detected 1 individual snow leopard on 1 detection from this region, and the estimated snow leopard density was 0.16 (0.03 - 0.80) per 100 km².



Deepti Bajaj



Wildlife Wing - HPFD and NCF

The woolly flying squirrel (left) & the Pallas’s cat (right) were first time records from the state

Table 3: List of non-targeted species detected across various sites

Species	Kinnaur	Tabo	USL	Pin	Lahaul-Pangi	GHNP
Himalayan wolf (<i>Canis lupus</i>)	5	1	7	-	3	-
Common leopard (<i>Panthera pardus</i>)	20	-	-	-	1	50
Himalayan brown bear (<i>Ursus arctos</i>)	1	-	-	6	13	2
Red fox (<i>Vulpes vulpes</i>)	584	587	190	184	306	54
Stone marten (<i>Martes foina</i>)	52	97	53	77	95	20
Yellow-throated marten (<i>Martes flavigula</i>)	1	-	-	-	5	11
Leopard cat (<i>Prionailurus bengalensis</i>)	-	-	-	-	1	24
Pallas’s cat (<i>Otocolobus manul</i>)	3	-	-	-	-	-
Mountain weasel (<i>Mustela altaica</i>)	-	5	5	3	15	2
Himalayan ibex (<i>Capra sibirica</i>)	15	1	31	29	15	-

The numbers represent the site-wise number of detections of each species

Species	Kinnaur	Tabo	USL	Pin	Lahaul-Pangi	GHNP
Himalayan musk deer (<i>Moschus leucogaster</i>)	-	-	-	-	21	13
Himalayan tahr (<i>Hemitragus jemlahicus</i>)	-	-	-	-	-	33
Goral (<i>Naemorhedus goral</i>)	-	-	-	-	-	55
Blue sheep (<i>Pseudois nayaur</i>)	47	62	44	3	1	15
Sambar deer (<i>Rusa unicolor</i>)	-	-	-	-	-	1
Rhesus macaque (<i>Macaca mulatta</i>)	2	3	-	-	3	14
Himalayan langur (<i>Semnopithecus schistaceus</i>)	-	-	-	-	-	50
Pika (<i>Ochotona sp.</i>)	11	177	243	110	409	179
Woolly flying squirrel (<i>Eupetaurus cinereus</i>)	-	-	-	-	12	-



Wildlife Wing - HPFD and NCF

Snow Leopards and Prey

Mountain ungulates - blue sheep and ibex - are key determinants of snow leopard population. It is widely accepted that the availability of the wild ungulates determines the population of the large carnivores (Karanth et al., 2004). Research depicts that areas with high wild ungulate densities have potential to support healthy snow leopard populations (Suryawanshi et al., 2021). Monitoring densities of the wild ungulates is critical for effective conservation of snow leopard and their habitat. Snow leopard and wild ungulate populations are being monitored for several years in the USL. The double observer method

(Suryawanshi et al., 2012) which is based on mark-recapture theory is used to estimate the abundance of wild ungulates in Spiti. This is done by dividing the study site into smaller blocks based on the topological features. Two teams independently surveyed each block on foot, with a temporal gap of 15-30 minutes. For snow leopard monitoring, we estimated their density using camera trap data analysed with SECR for USL. Here we present results for prey and snow leopard numbers continually being monitored between the first round of the state population estimation of snow leopard till now.

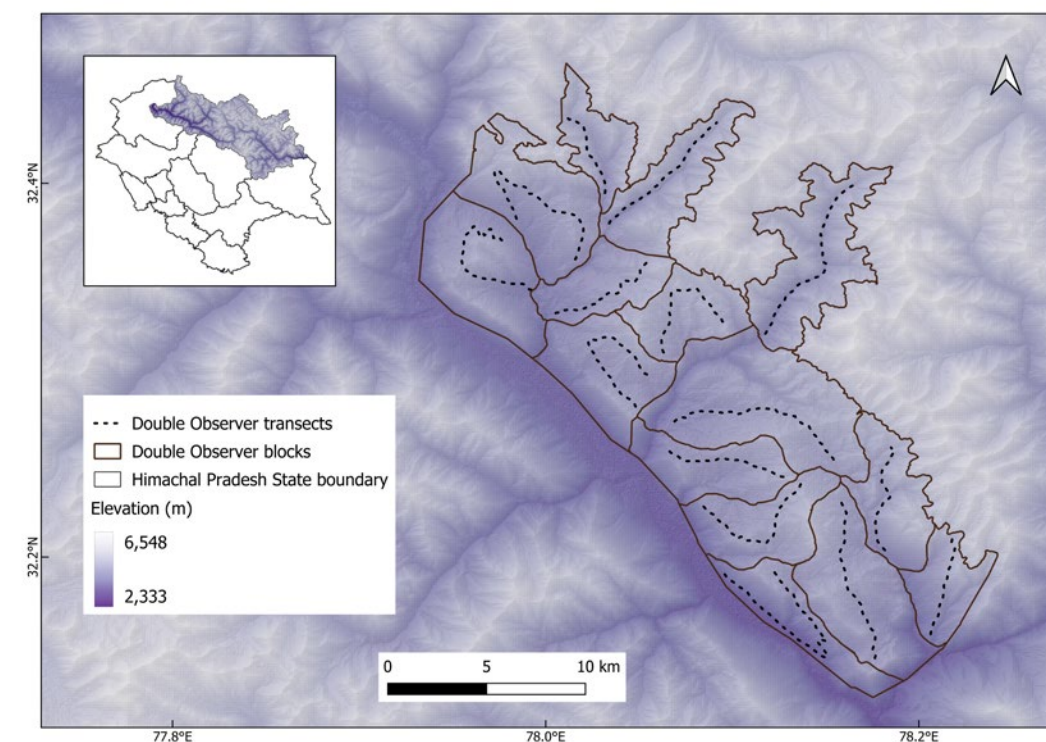


Figure 4: Map showing the Kibber double observer sampling region from USL for ungulate survey

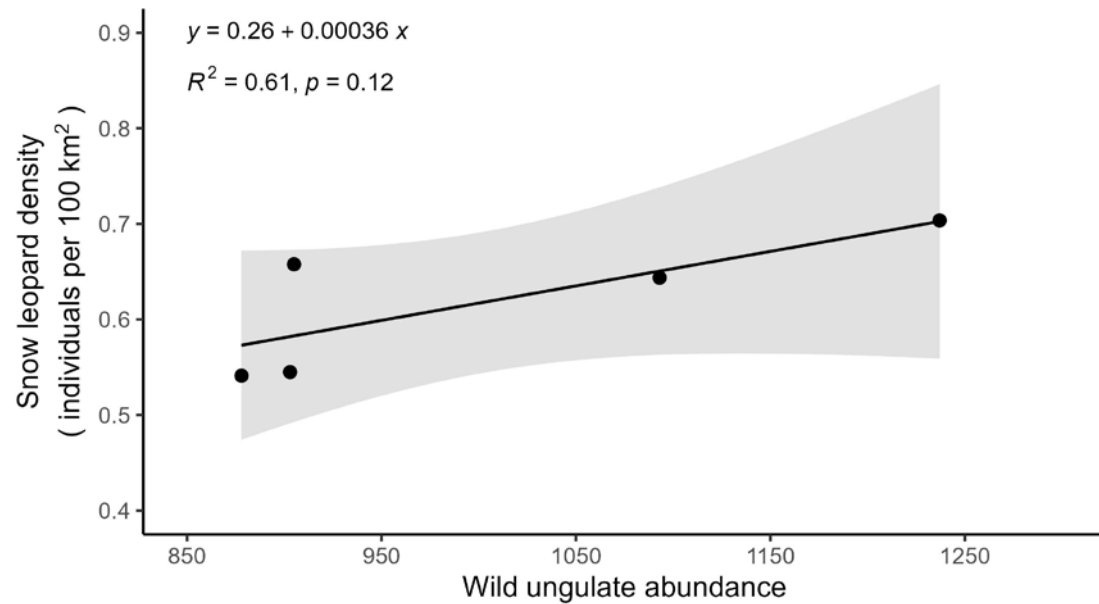


Figure 5: Snow leopard density (individuals/100 km²) and wild prey abundance from USL in the past five years. Line represents predicted relationship from a simple linear regression model (slope = 0.26, SE=, R²= 0.61, p=0.12) and the shaded region represents 95% CI on the model predictions

We found fluctuations in wild ungulate abundance over the years, and the snow leopard density has largely remained constant. Blue sheep abundance fluctuated in abundance from 786 in the year 2020 to 1094 in the year 2024, whereas ibex fluctuated in abundance from 92 in the year 2020 to 146 in the year 2024. Snow Leopard densities have fluctuated from being 0.5 (95% CI: 0.28 - 1.01) in the year 2020 to 0.7 (95%

CI: 0.38 - 1.27) in the year 2024. Snow leopard populations show a linear relationship with wild prey populations.

However, population trends are often non-linear, and can fluctuate due to various factors such as changes in habitat, climate variability, predation, disease outbreaks and human influence. Sustained monitoring and long-term

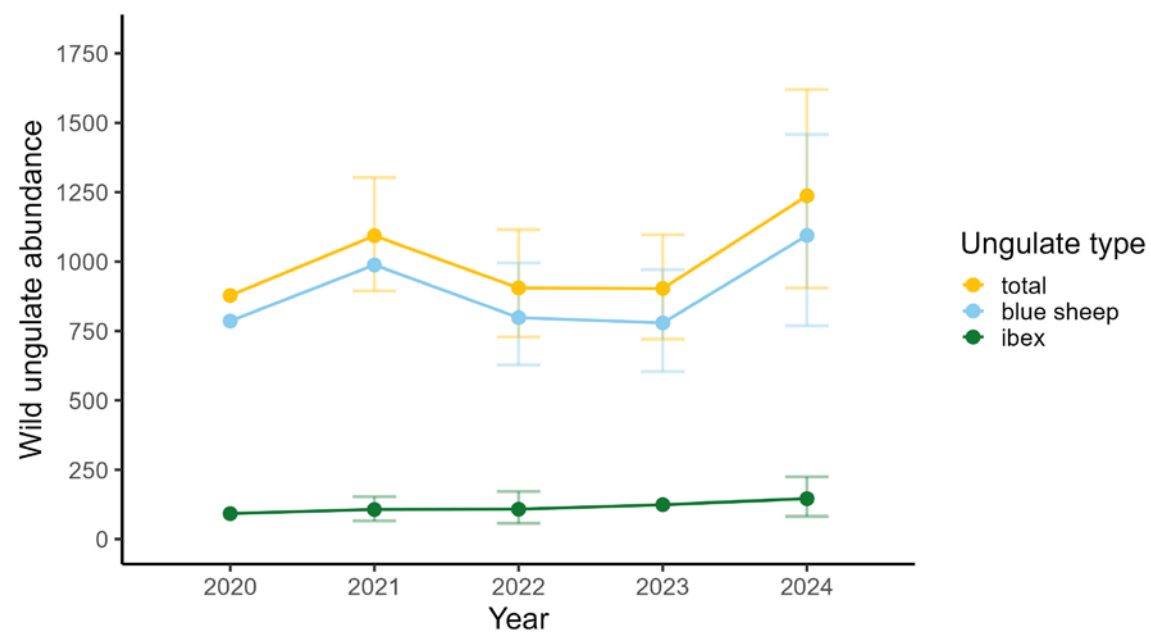


Figure 6 - Trends in wild ungulate abundance of USL from 2020 to 2024 monitored annually

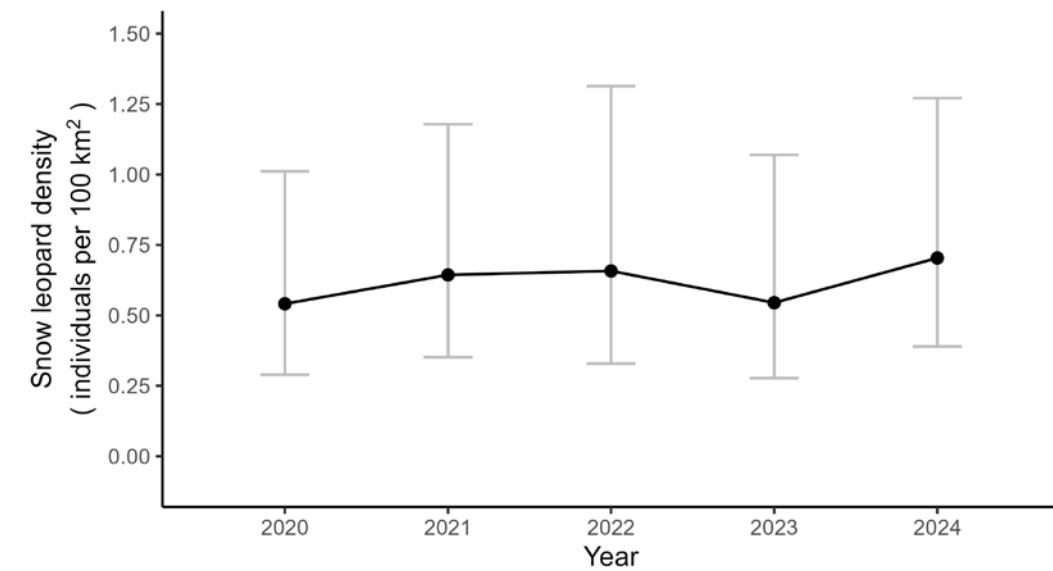


Figure 7 - Trends in snow leopard density of USL from 2020 to 2024 monitored annually using SECR

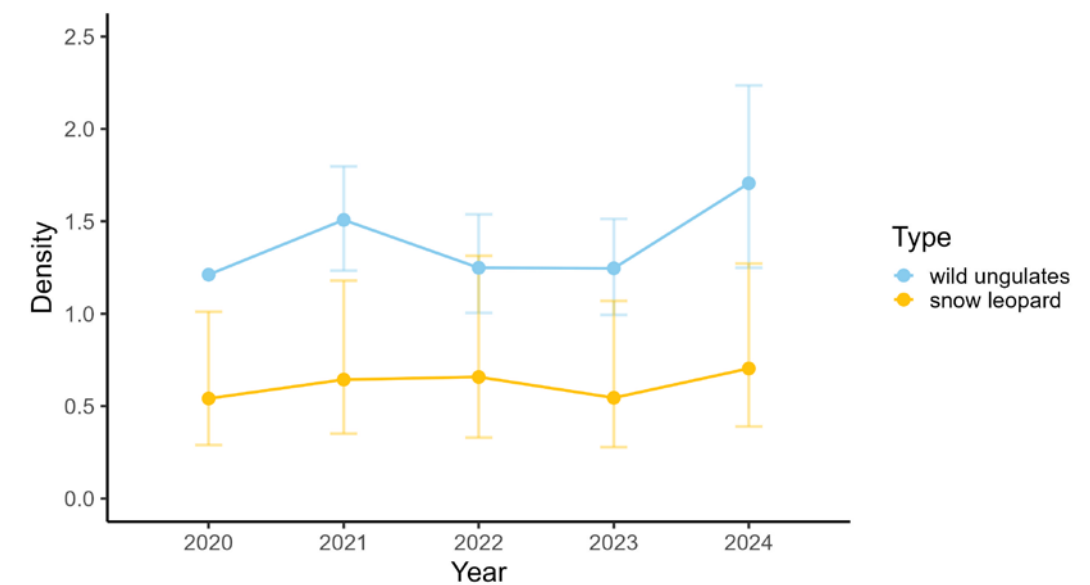
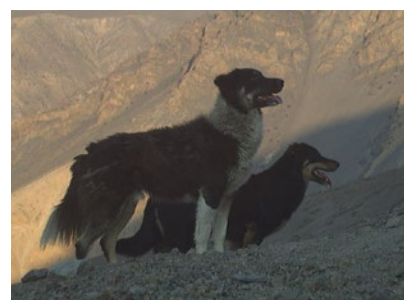


Figure 8 - Trends in wild ungulate density (individuals/km²) with respect to snow leopard density (individuals/100 km²)

data helps detect cycles and fluctuations and assess conservation effectiveness to help in making informed management decisions. Long-term monitoring also gives us insights into the population dynamics of species such as birth rates, death rates and female land tenure.

Snow leopard populations show a linear relationship with wild prey populations.



All images - Wildlife Wing - HPFD and NCF

Distribution of other mammals in the snow leopard landscape of Himachal Pradesh

This large scale camera trapping exercises across the state also recorded other mammals residing in snow leopard landscapes of Himachal Pradesh. In 2024, we got a newer and first time record for two species, the Pallas's cat *Otocolobus manul* record near Nako from Kinnaur, and the Woolly flying squirrel *Eupetaurus cinereus* record from Miyar valley in Lahaul. While the primary focus of the camera trap surveys was to monitor snow leopards, the extensive network of deployed cameras has also provided valuable insights into the distribution of non-targeted species such as: Blue sheep *Pseudois nayaur*, Himalayan brown bear *Ursus arctos*, Himalayan wolf *Canis lupus*, Himalayan ibex *Capra sibirica*, common leopard *Panthera pardus*, mountain weasel *Mustela altaica*, Himalayan musk deer *Moschus leucogaster*, red fox *Vulpes vulpes*, stone marten *Martes foina* and yellow-throated marten *Martes flavigula*. The incidental detections of these mammals contribute to refining range maps, documenting previously unrecorded occurrences, and identifying critical biodiversity hotspots within the landscape. These findings enhance our understanding of species distribution, habitat use,

and potential ecological corridors, offering crucial data for conservation planning beyond snow leopards.

Making Species Distribution Models

We used an ensemble modeling approach with the R package SSDM (Schmitt et al., 2017) to estimate the distribution of non-targeted species. This method integrates multiple Species Distribution Models (SDMs), selecting the best-performing algorithms and combining their predictions for more reliable results (Araújo & New, 2007). Previous studies have shown that ensemble SDMs outperform individual models in accuracy (Ahmad et al., 2020). Model inputs included non-correlated environmental variables and spatially distinct occurrence points, with 70% used for calibration and 30% for testing. To improve model reliability, we generated 200–1000 pseudo-absence points over 10 iterations using a random strategy (Barbet-Massin et al., 2012; Zhuo et al., 2022).

The extensive network of deployed cameras has also provided valuable insights into the distribution of non-targeted species.



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The model outputs were evaluated using true skill statistics (TSS), Kappa, and the area under the curve (AUC) of a receiver operating characteristic (ROC) curve, where values above 0.8 indicate excellent performance (Allouche et al., 2006). This approach provides a robust framework for mapping species distributions, offering insights into habitat use and potential biodiversity patterns in the region.

The ensemble model performed well across all non-targeted species, with AUC values ranging from 0.92 to 0.99, indicating high predictive accuracy. Sensitivity, specificity, and proportion correctly classified were consistently high, while Kappa values, ranging from 0.72 to 0.85, suggest substantial agreement, confirming the reliability of the model in mapping species distributions.

Table 4. Calibrations of the model used in the ensemble model

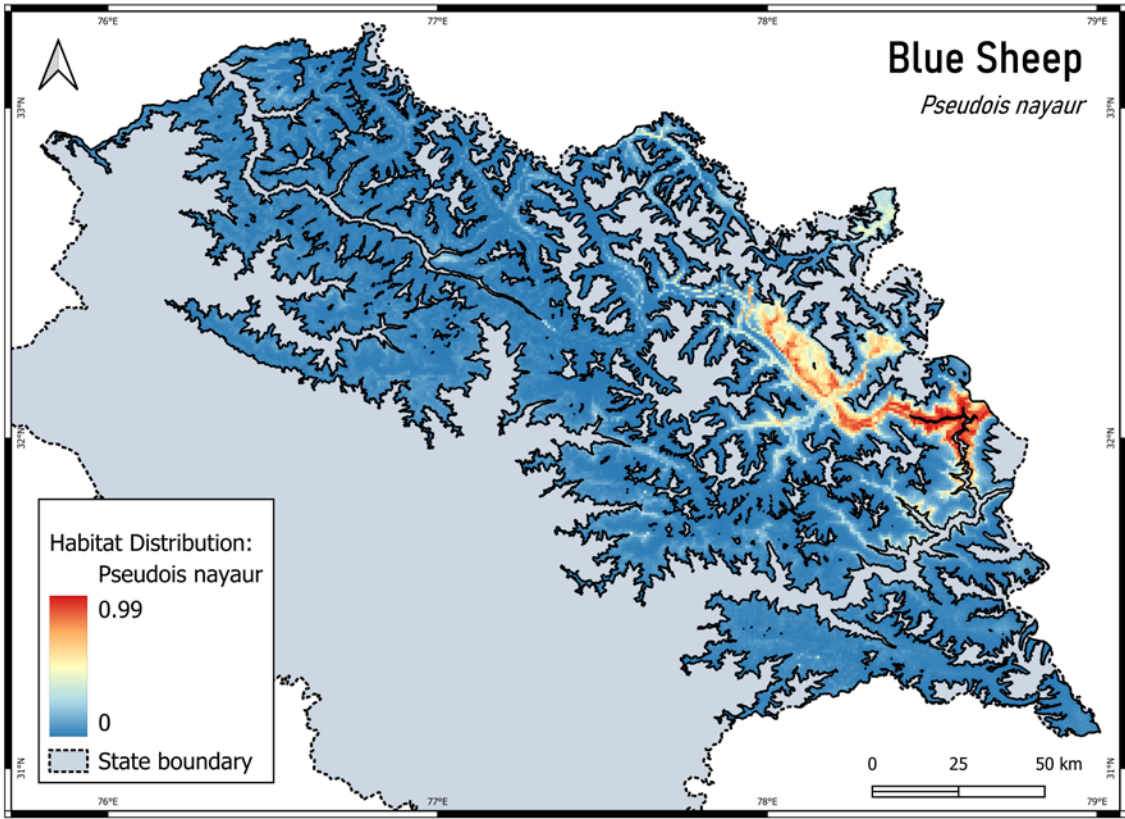
Metric	<i>Pseudois nayaaur</i>	<i>Ursus arctos</i>	<i>Panthera pardus</i>	<i>Capra sibirica</i>	<i>Moschus leucogaster</i>	<i>Mustela altaica</i>	<i>Martes foina</i>	<i>Vulpes vulpes</i>	<i>Canis lupus</i>	<i>Martes flavigula</i>
AUC	0.97	0.96	0.97	0.98	0.98	0.92	0.94	0.93	0.99	0.95
Omission rate	0.02	0.08	0.05	0.04	0.03	0.08	0.10	0.11	0.01	0.05
Sensitivity	0.90	0.95	1	0.96	0.98	0.91	0.90	0.90	1	0.95
Specificity	0.98	0.92	0.95	0.96	0.96	0.93	0.90	0.88	0.98	0.95
Prop. Connect	0.98	0.92	0.95	0.96	0.96	0.92	0.90	0.89	0.98	0.95
Kappa	0.85	0.82	0.72	0.74	0.84	0.77	0.74	0.73	0.82	0.77

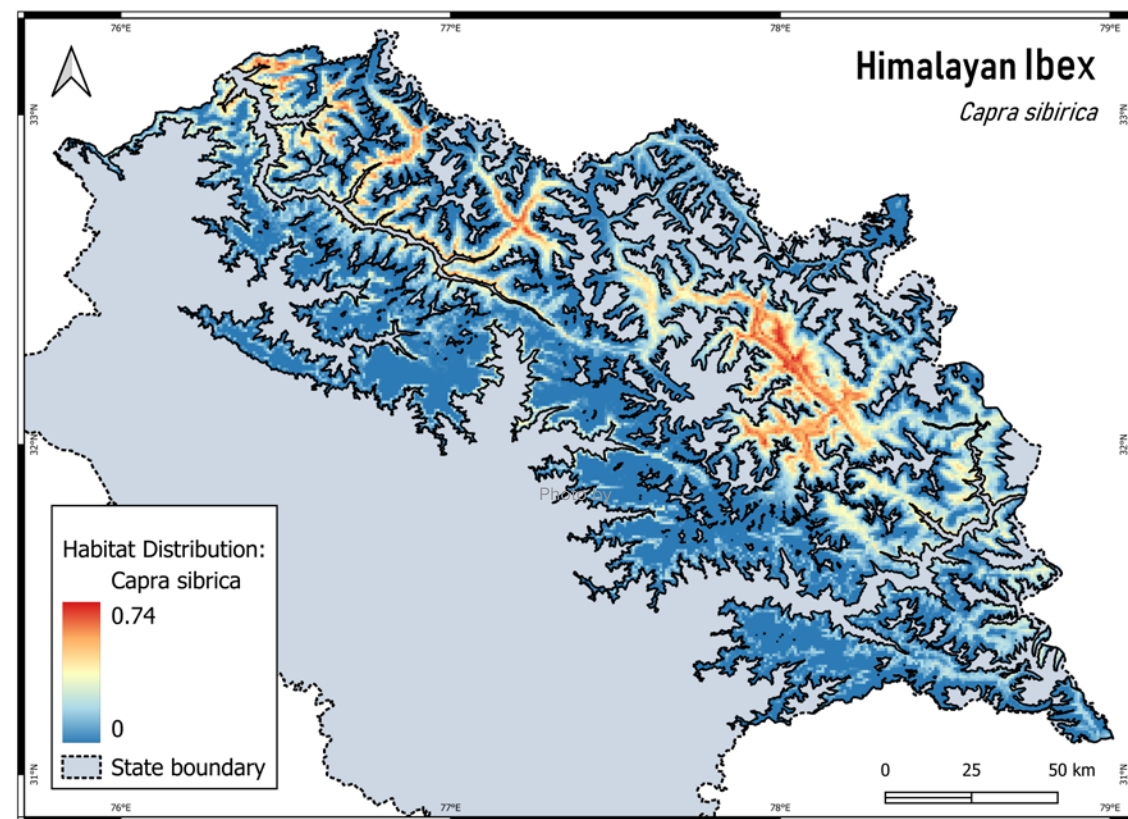
Results

As seen from the ensemble outputs, the two main prey species of the snow leopard, ibex and blue sheep are found dispersed across the snow leopard landscape of Himachal Pradesh. The Ibex occurs primarily in rugged areas from around Pin valley in Spiti going west, including regions of Kibber to Lossar in Spiti and large areas of Lahaul including Bhaga, Miyar and Chandra valleys. Parts of Chamba (eg. Pangi and Bharmour) are also regions of high occurrence for them. Blue sheep on the other hand are a bit more restricted with high occurrence areas around Hangrang valley of Kinnaur and across the Spiti region, particularly Tabo and USL. They prefer more undulating areas with proximity to cliffs.

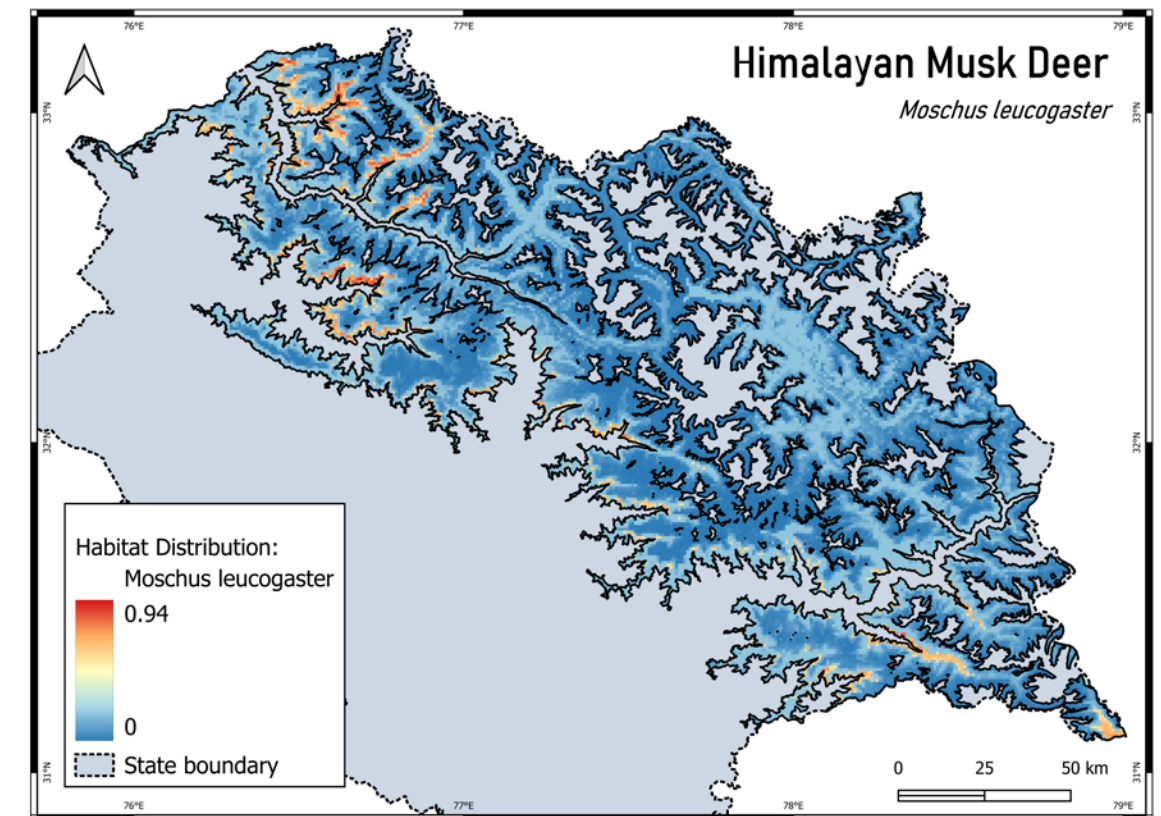


Kesang Chunit





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Musk deer were predicted to occur predominantly across the Greater Himalayas with particularly high occurrence in Chamba (especially Pangi), parts of Lahaul, Kullu and lower Kinnaur. Musk deer detections were mostly in areas near tree cover.

Brown bears were found to occur predominantly across the valleys in Lahaul, Chamba (eg. Pangi and Bharmour), and parts of Kinnaur. Additionally, they were found to occur at the edge of Pin Valley connecting towards the Kullu and Kinnaur regions. They seem to prefer regions along the valley, especially near meadows.



Wildlife Wing - HPFD and NCF

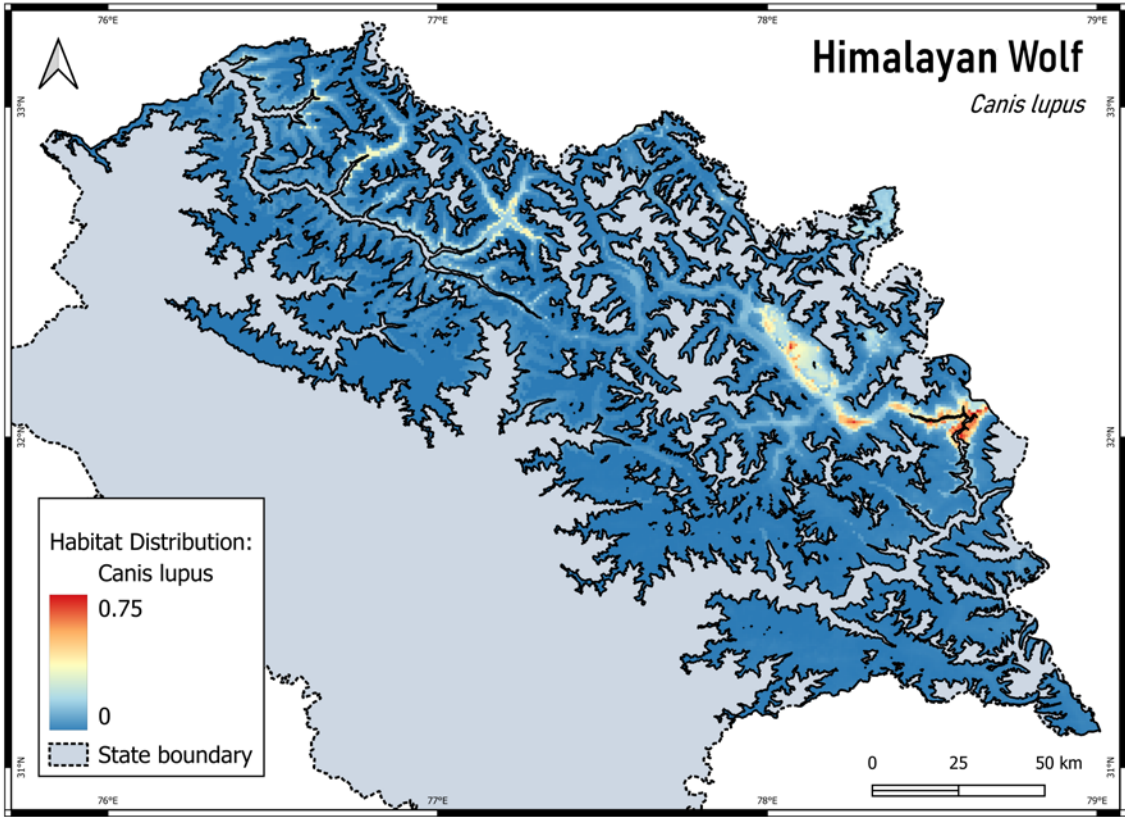
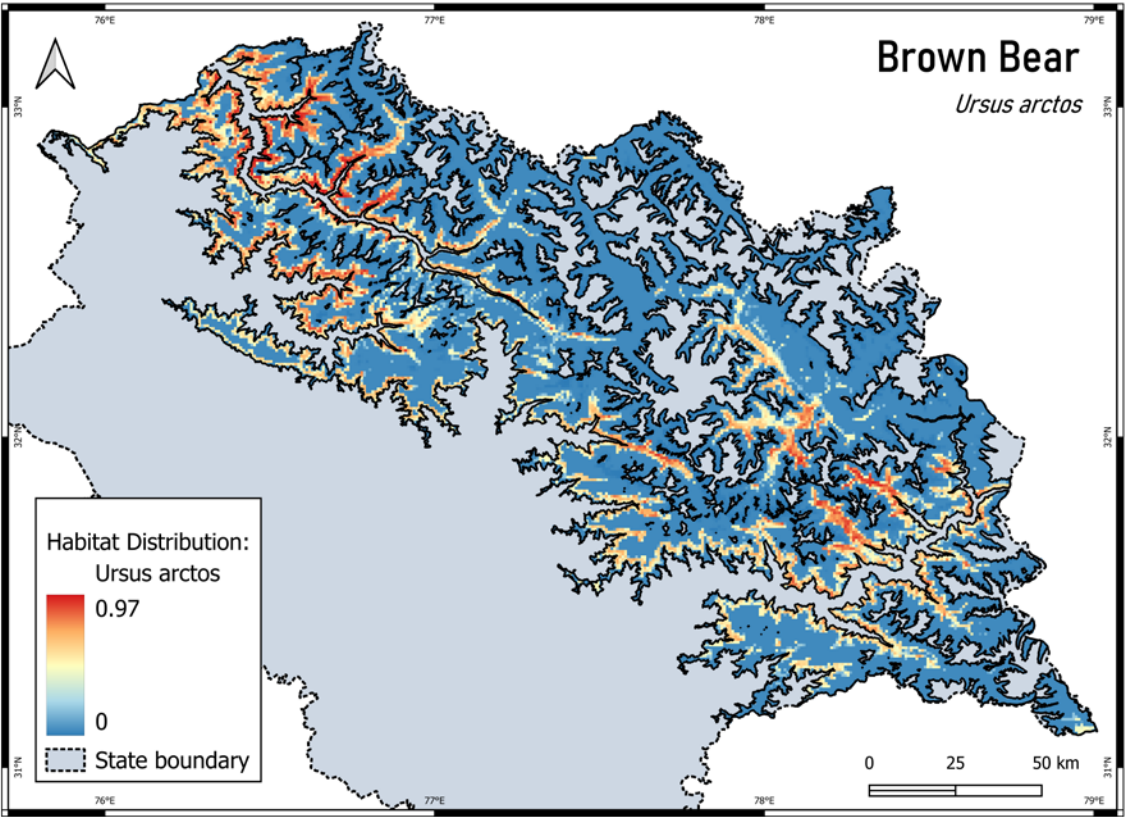


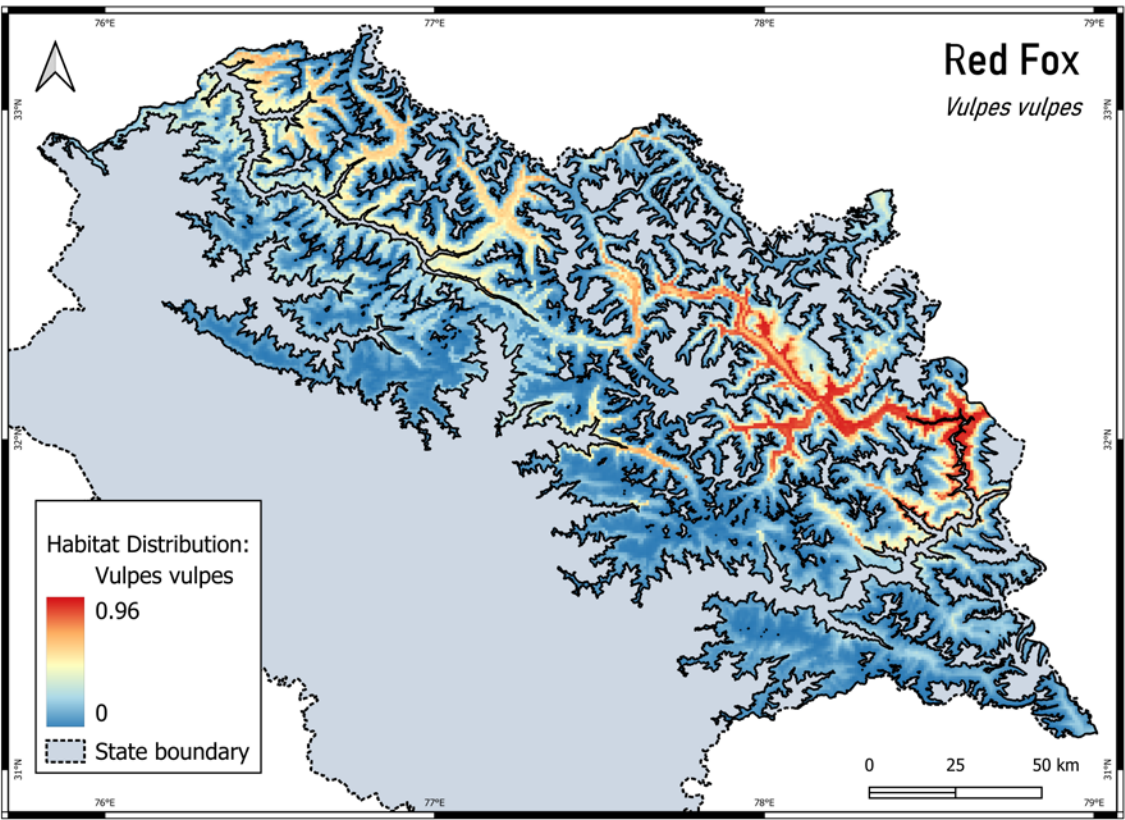
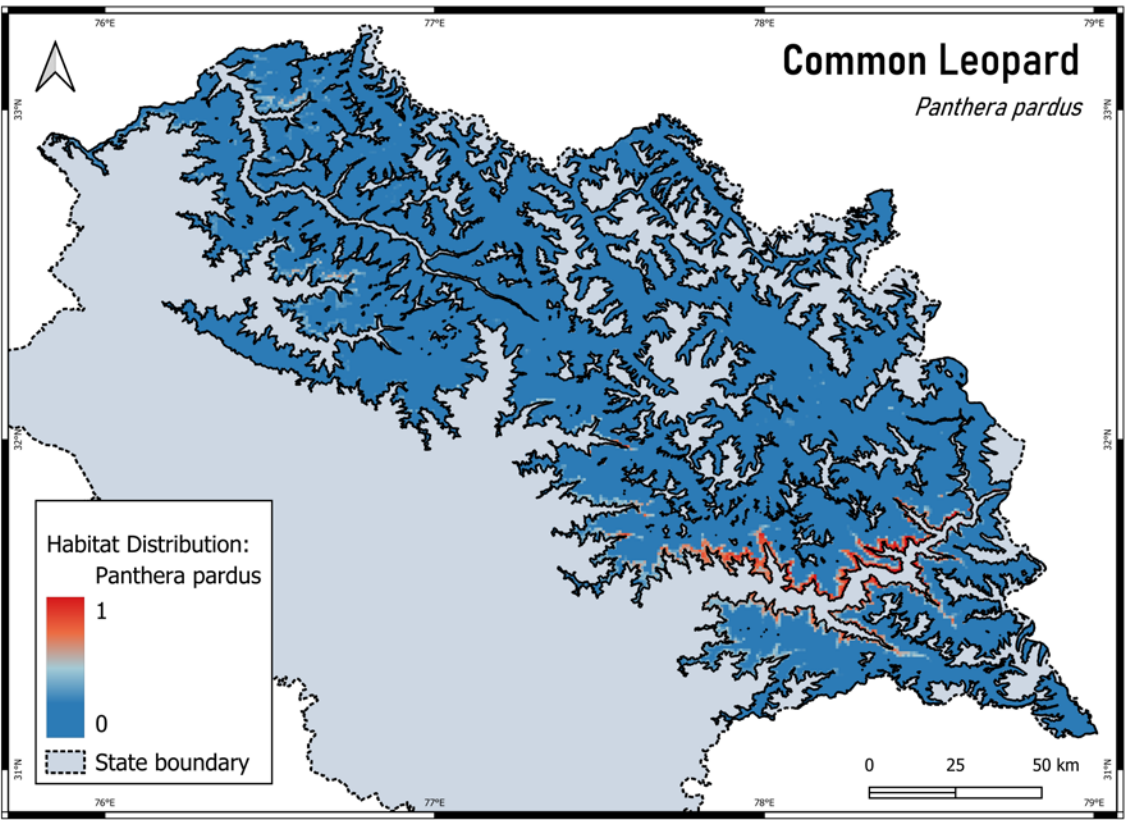
Wildlife Wing - HPFD and NCF



Wildlife Wing - HPFD and NCF

Wolves were seen to occur in more rolling, plateau-like areas around Spiti and Lahaul. Interestingly, common leopards were found to have high occurrence along the southern rims of the snow leopard distribution within Himachal Pradesh, with increased occurrence in parts of Kinnaur (upper and lower) and high elevations of Kullu and Chamba. They also were seen to occur in pockets of Lahaul.





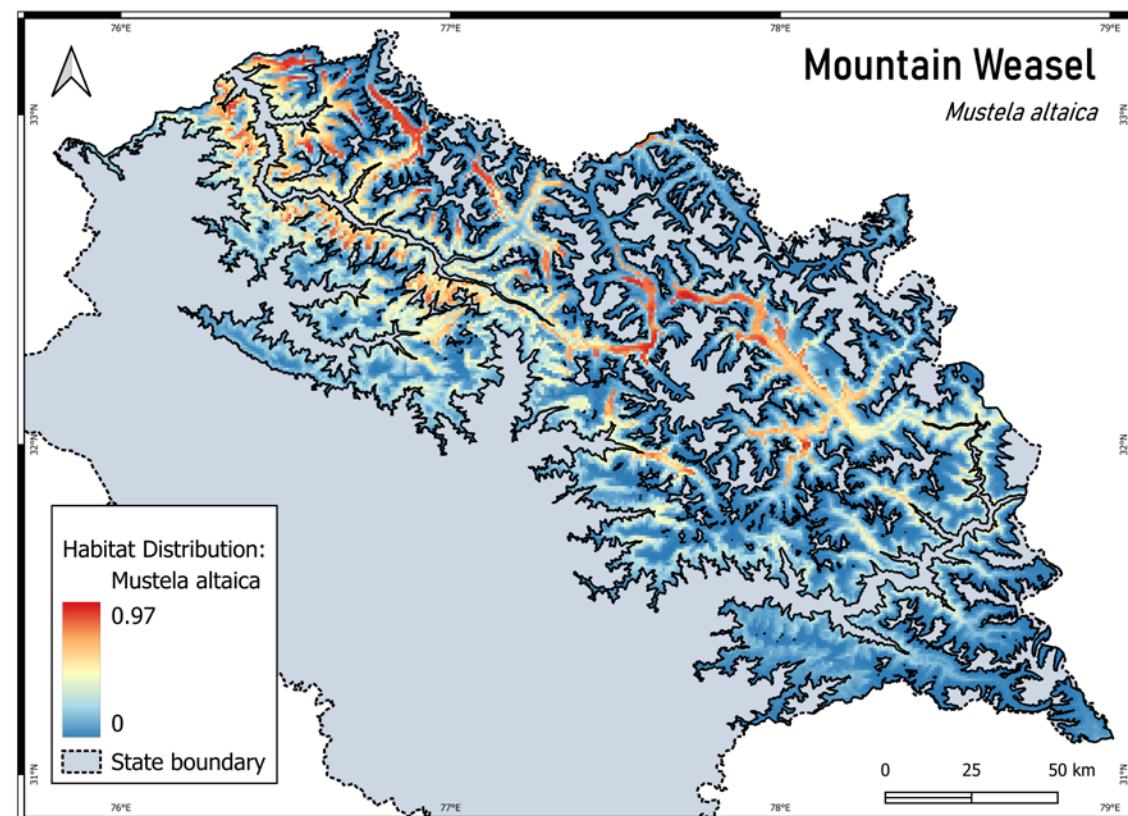
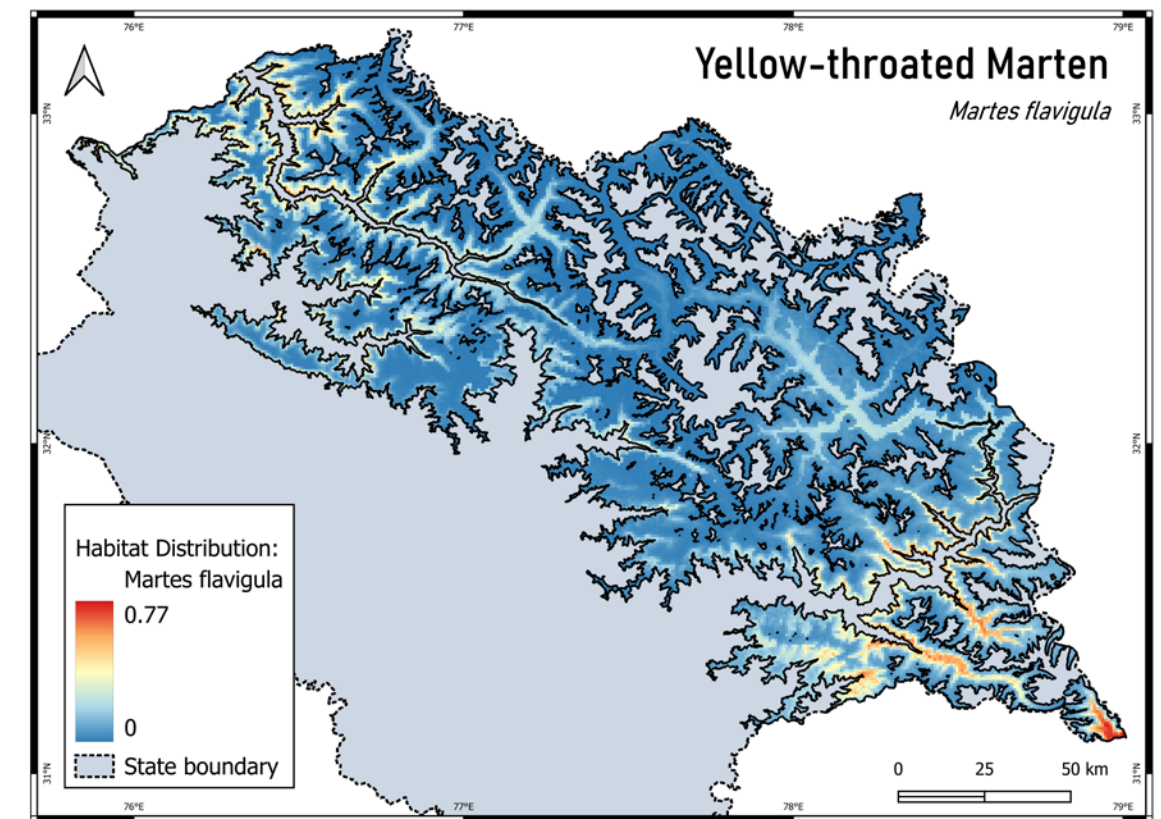
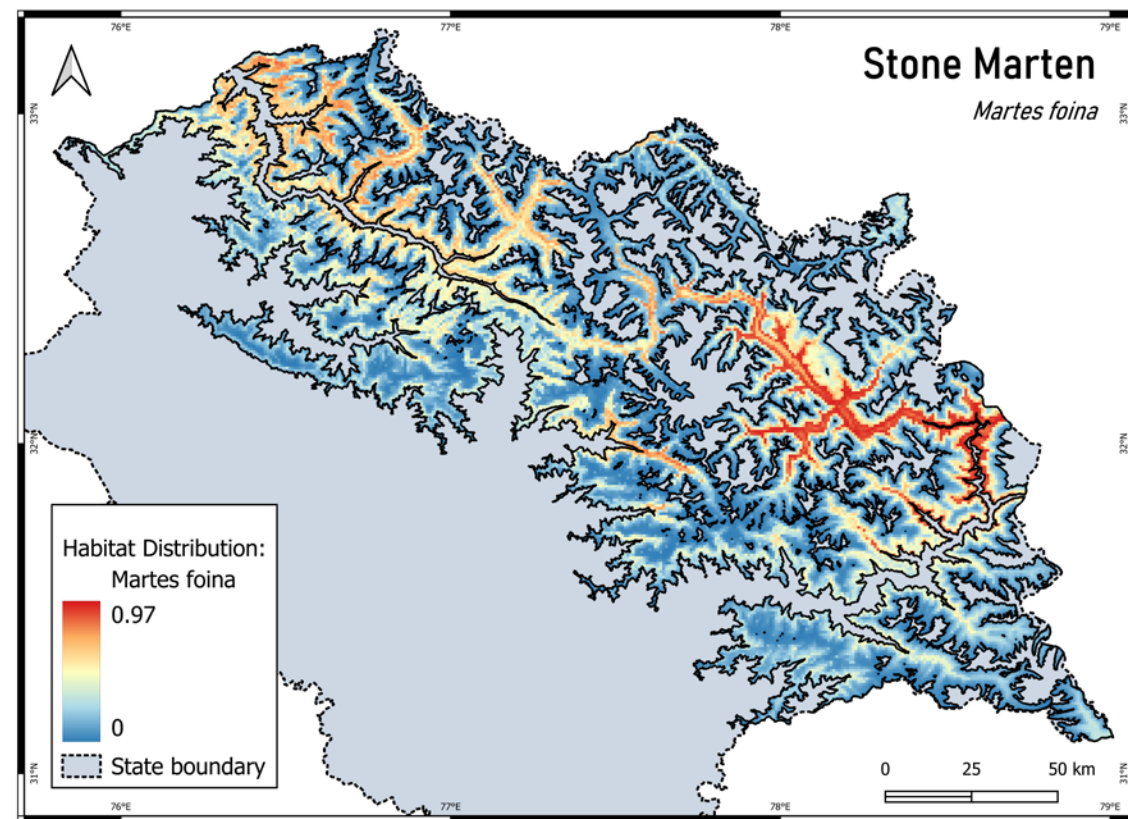
Wildlife Wing - HPFD and NCF



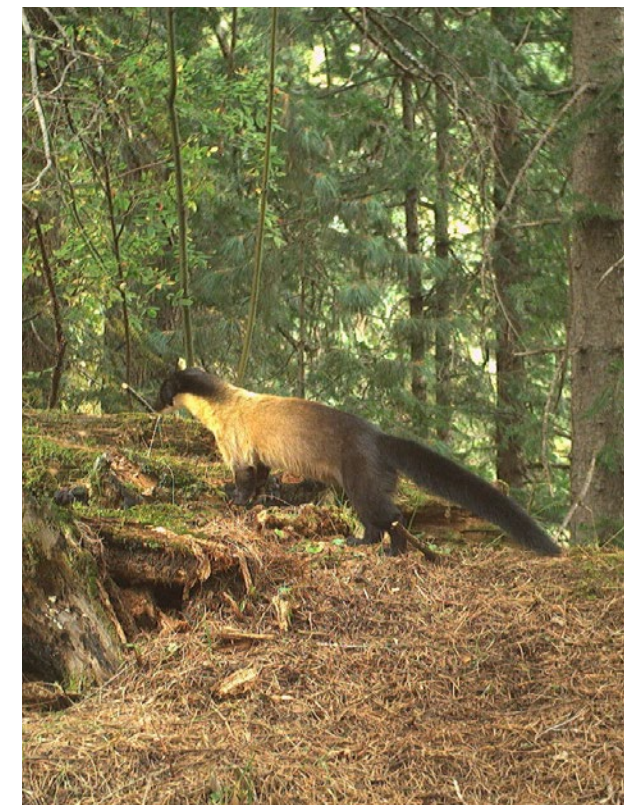
Wildlife Wing - HPFD and NCF

The three meso-carnivores, namely the red fox, stone marten and mountain weasel, were found to occur throughout the high elevation region. Stone marten and red foxes were seen to have higher occurrences around Upper Kinnaur and Spiti region (trans-Himalayas) whereas mountain

weasels had higher occurrences into Lahaul and Pangi in particular. Another meso-carnivore, the yellow-throated marten, was found to occur primarily across the Greater Himalayan region, in lower Kinnaur and Kullu.



The three meso-carnivores, namely the red fox, stone marten and mountain weasel, were found to occur throughout the high elevation region.





Capacity Building

State Forest Department

The Himachal Pradesh Forest Department plays a crucial role in snow leopard habitat conservation. Amongst the several key functions it performs, facilitating the exchange of knowledge and skill has remained a pertinent one across the years. It is in this spirit of collaboration that a workshop on snow leopard assessment techniques, camera trap deployment, and ungulate population surveys was carried out jointly with the Nature Conservation Foundation (NCF).

The training covered the following topics:

1. Introduction to Population Assessment of World's Snow Leopards (PAWS) and state-wide assessment of snow leopards.
2. Introduction to camera trapping survey for snow leopards and double observer survey for monitoring ungulates

20 staff members of the Spiti Wildlife Division, including the Deputy Conservator of Forests (DCF), Kaza, were provided with a detailed understanding of the Snow Leopard Population Assessment of India (SPAII) guidelines and data collection protocols for this exercise. They were apprised about the workflow and data processing that was followed by fieldwork. A hands-on session on deploying camera traps was also given to understand its settings and features. They were also introduced to the double observer survey method used to assess and monitor mountain ungulates in the trans-

Himalayan landscape. The staff of Spiti Wildlife Division along with a team of 10 locals from Kibber village, Spiti, completed the fieldwork for camera trapping exercise and the double observer survey in Spiti. Frontline staff from Lahaul Forest Division and Great Himalayan National Park also participated in the fieldwork.

Field manuals and brochures on camera trapping work and double observer field survey were also shared with the forest department along with other resources.





Akshata Anand



Charu Sharma



NCF

Local Champions

The teams involved in camera trapping face significant challenges, as their fieldwork takes them through some of the most arduous and remote terrains imaginable. Snow leopard habitats are often difficult to access treacherous landscapes, which can involve steep cliffs and rocky and unstable ground. These conditions make the task of monitoring elusive species like the snow leopard incredibly demanding, both physically and logistically. The work itself is

time-consuming, often stretching across many months, and can be exhausting, particularly when traveling to far-flung locations.

However, the difficulty of this work was considerably alleviated thanks to the unwavering support and involvement of local communities. The local communities possess intimate knowledge of the land and its natural features. Hence, in each of the landscapes, we first briefed

the community about what we were doing and then we engaged a few interested individuals from those communities. Their active participation and guidance in the camera trapping process has played a crucial role in making the camera trapping efforts more efficient. In each of the sessions, the local communities were notified about the camera trapping exercise to ensure transparency, respect privacy and prevent any feelings of intrusion, and encourage their participation and support in the initiative. After this first engagement, a select few interested individuals were then engaged as members of that camera trapping team.

Engaging the locals of Himachal Pradesh, fieldwork for the entire camera trapping exercise was led by the local community members and champions from various regions including Hango from Kinnaur, Kibber from Spiti and Hudan from Lahaul-Pangi. In total at least 23 people from the Himachal Pradesh's snow leopard landscape were involved in the survey. They were adequately supported by NCF researchers, frontline staff of HPFD and other villagers. Without the meaningful involvement of these local champions, it would not have been possible to cover such large areas in such a short period of time.

Without the meaningful involvement of these local champions, it would not have been possible to cover such large areas in such a short period of time.

We can now leverage the connection built with these local champions to engage in long-term community-based conservation in each of these areas. In the very plausible scenario of uncertain changes to snow leopard habitats, this model of collaboration offers a hopeful and sustainable path forward—one where local communities are empowered as stewards of the environment, helping to protect and preserve the world's most vulnerable species for generations to come. This initial touch with studying snow leopard stays there for long-term engagement with the local communities for conservation action.



NCF



Deepti Bajaj

Women of Spiti

Women in the snow leopard landscape have been at the center of habitat management and conservation of fragile ecological systems. Traditionally, women have been responsible for soil and water management (Murali et al., 2021). This embedded connection to the land, built over generations, contributes to the preservation of snow leopard habitats.

However, the role of these women extends beyond traditional conservation practices. A group of eleven women from the village of Kibber have made key contributions to this report. Trained to set up and operate camera traps, these women have become an essential part of the monitoring process for snow leopards and other wildlife in the area. The women's involvement in camera trapping went far beyond just setting up the devices. They demonstrated remarkable skill in analyzing the images that the cameras captured. The women's expertise in identifying

snow leopards and other species, as well as their ability to tag images with accurate data, made a significant impact on the research. Their attention to detail and commitment to accuracy ensured that the data collected was reliable and valuable for the overall analysis.

Thanks to the women's efforts, the research teams were able to process and analyze data much faster than initially anticipated. Their story is a powerful reminder of the importance of gender-inclusive conservation work. The women from Kibber, through their training and determination, proved that with the right support and resources, local communities, particularly women, can play a transformative role in biodiversity conservation. This model of collaboration between local knowledge and scientific tools is a promising path forward in the ongoing effort to protect endangered species and the ecosystems they depend on.



Deepshikha Sharma



Deepshikha Sharma

The women's involvement in camera trapping went far beyond just setting up the devices. They demonstrated remarkable skill in analyzing the images that the cameras captured.



Sonam Dolma

Discussion

The second round of population estimation in Himachal Pradesh estimated 83 individuals (95% CI: 67-103) compared to an estimate of 51 (95% CI: 44-73) snow leopards in the first round. While our results suggest an increase in the population of snow leopards from the first population estimation exercise, this increase in estimate needs to be interpreted with some considerations.

Firstly, it is particularly important to note that the minimum count of snow leopards were the same for the first round and this round of estimation in Himachal Pradesh. This was 44 individuals. The overlapping confidence intervals between the two estimates make it difficult to interpret this as an actual increase in estimated population for the state. Secondly, we found a marked difference in the sigma parameter between the first round of population estimation which was 8.5 (95% CI: 6.9-10.41) km, to the second round of population estimation - 5.2 (95% CI: 4.7-5.8) km. Sigma is the movement parameter and can be interpreted as an index of home range. A higher sigma is indicative of larger movement by individuals and can be influenced by various factors such as sex ratios of the population, overall population densities and landscape features to state a few. A higher sigma often results in lower densities, whereas a smaller sigma tends to increase densities (Efford et al., 2016). For snow leopards across their global range, sigma tends to range

It was heartening to find breeding individuals across most of the areas in the state.

from around 3.0 km till about 5.5 km (Alexander et al., 2015; Bian et al., 2023; Chetri et al., 2019). Therefore, further investigations are needed to understand why there was a large reduction in sigma between the two surveys - which could explain the large jump from our minimum count to our estimated population, unlike in the first round of population estimation. Thirdly, we reduced the time taken to do this survey from three years to one year, which could have impacted results, for instance by potentially impacting the sigma given that sampling occurred in slightly different seasons during the first round of estimation. Fourthly, having done this exercise once before, it is likely that the team was better equipped and trained in conducting the field work and analysis this time around. This could have led to improved and more voluminous data, also influencing the shape of the detection functions.



Wildlife Wing - HPFD and NCF

Besides just population estimates for Himachal Pradesh as a state, it was heartening to find breeding individuals across most of the areas in the state. Moving forward, it is critical to understand not just population numbers but also population dynamics (Sharma et al., 2014). Part of this is to understand patterns of birth and death rates of snow leopards and also how their populations are connected. Therein, it is key to move beyond just studying snow leopards in isolated sites, but take a landscape level approach of understanding multiple snow leopard populations in tandem to investigate how they might be interacting with each other (Johansson et al., 2016). Besides snow leopards, as seen from the results for other sympatric mammals during

this camera trapping exercise, it is clear that snow leopards can be leveraged as umbrella species to safeguard numerous other mammals across high elevation Himachal Pradesh. Going forward, it will be crucial to understand prey-predator dynamics in particular to make sense of changes in snow leopard estimates through time.

Nevertheless, while snow leopard numbers are not decreasing in Himachal Pradesh, they still face significant threats to their populations. From attempted retaliatory measures due to their livestock depredation behaviour, to loss of habitat to ill planned development projects, there is still need for active and innovative conservation interventions that are context specific (Bijoor

et al., 2021). In particular, there is a worrying trend of increased presence and impact of free-ranging dogs across snow leopard habitat. We found free-ranging dogs across most of the areas where we placed camera traps. Free-ranging dogs are known to transmit diseases to snow leopards, kill wildlife including the key prey species of snow leopards, and chase snow leopards from their kills. Concerted effort is needed to deal with the issue of free-ranging dogs in these landscapes. Interestingly, we also found more common leopard captures than in the first round of population estimation. The impact of common leopards on snow leopards, if any, needs investigation.

Finally, being able to reduce the time of the entire effort from around three years to about one year is a testament to the various committed Forest Department officials and local champions, especially the dedicated team of women researchers in Kibber. It is only with collaboration between such local stakeholders can continual population monitoring of snow leopards happen, while meaningful conservation interventions are scaled to secure the habitats and populations of the ghost of the mountain.

Interestingly, we also found more common leopard captures than in the first round of population estimation. The impact of common leopards on snow leopards, if any, needs investigation.



Wildlife Wing - HPFD and NCF

Future Directions

This project is a scientifically robust and repeatable assessment of snow leopard populations in Himachal Pradesh, making it the first state in India to conduct such a comprehensive survey twice. By doing so, it lays a blue print for other snow leopard regions to follow and ensure long-term monitoring of this elusive species. It is also among the few initiatives globally to achieve this scale within the snow leopard's range. By reducing the survey duration from three years to one, it establishes a cost-effective, replicable model for continuous monitoring. The findings track population changes, contribute to assessing conservation impacts, and identify areas needing targeted efforts, reinforcing Himachal Pradesh's leadership in snow leopard conservation.

To ensure the long-term conservation of snow leopards and their habitats, it is essential to continue periodic monitoring of snow leopard populations, with annual assessments of both snow leopards and their prey in key sites like Spiti, Lahaul-Pangi and Kinnaur. Larger scale assessments such as across Himachal Pradesh can be done periodically - perhaps once every three-five years. Expanding wildlife monitoring efforts through large-scale camera trapping will provide broader insights into ecosystem health. Additionally, more research

This project is a scientifically robust and repeatable assessment of snow leopard populations in Himachal Pradesh, making it the first state in India to conduct such a comprehensive survey twice.

can focus on the potential expansion of common leopard range into higher elevations and on the understanding of co-predator interactions. This will help in the preparation for potential conflict scenarios. The knowledge produced thus far sets a strong foundation on which to build up better understandings of the motivations and views of local communities, who must remain central to all conservation efforts. The blending of their perspectives and traditional knowledge into conservation plans must be a continued

imperative. This not only builds local stewardship but also strengthens conservation outcomes. Furthermore, landscape-level conservation strategies are needed to address land-use changes and the looming threat of climate change, assessing local impacts to plan effective mitigation measures. By promoting traditional practices that have long preserved snow leopard habitats, and by fostering synergies between scientific and community-based approaches, a sustainable and improved model for wildlife conservation can be developed, tailored to the unique needs of high-altitude ecosystems.

The knowledge produced thus far sets a strong foundation on which to build up better understandings of the motivations and views of local communities, who must remain central to all conservation efforts



Acknowledgements



Charu Sharma

The project was carried out as a collaborative effort by the Wildlife Wing of Himachal Pradesh Forest Department and Nature Conservation Foundation, Mysuru. Several officers of the Wildlife Wing of Himachal Pradesh Forest Department played an important role across various stages of this project. We list the names of all these officers, field officers and frontline staff in acknowledgement of the role they played in ensuring the success of this project:

PCCF-cum-Chief Wildlife Warden -
Shri Amitabh Gautam (IFS)

APCCF - Dr. Pushendra Rana (IFS)

Conservator of Forests for Spiti & Kinnaur (South) - Smt. Preeti Bhandari (IFS)
Conservator of Forest for Lahaul -
Shri. Sandeep Sharma (IFS)
Conservator of Forest for Chamba -
Shri. Abhilash Damodaran (IFS)

DFO (HQ): Smt. Sheetal Sharma

Kinnaur Forest Division

DC - Shri. Amit Kumar Sharma
DFO - Shri. Arvind Kumar
RFOs

The Indo Tibetan Border Police officials

Nako BO - Naresh Kumar

Spiti (Wildlife) Division:

ADC (2024 incharge) - Shri. Rahul Jain &
Smt. Shikha Simtia
DFO (Wildlife) - Shri. Mandar Umesh Jeware
ACF - Shri. Chaman Lal
RFO - Shri. Prem Singh
Frontline staff of the Spiti Wildlife Division -
Arjun Singh, Devinder Kumar, Lovepreet Samta,
Narendra Kumar, Pankaj Sharma, Pradeep Kumar,
Pramod Verma, Rajesh, Shalig Ram, Shanta
Kumar, Kunga, Raju, Rohit Sharma, Rakesh

Lahaul Forest Division:

DC - Shri. Rahul Kumar
DCF - Shri. Aniket Maruti Wanve
Frontline staff- Shivkumar

Chamba Wildlife Division:

DFO (Wildlife) - Shri. Kuldeep Singh Jamwal
RFOs of Wildlife Sechu Tuan - Ajay
Sechu Tuan Forest rest house caretaker- Himlal
Pangi:
DFO Pangi (Territorial) - Shri. Divender Singh
Dhadwal
RC - Smt. Ritika Jindal

Lippa-Asrang (Wildlife) Division:

DFO Sarhan - Shri. Ashok Negi
RFOs
Forest Guard - Rakesh Lama

The Great Himalayan National Park (GHNP):

Director & Conservator of Forests - Smt. Meera
Sharma, & Shri. Sandeep Sharma
DFO (Wildlife) at GHNP - Shri. Sachin Sharma
RFOs of Sainj, Tirthan
Forest Guards: Bintu Thakur
Sainj Rest house caretaker- Govind Ram

Other supporters and local champions -
All guest house caretakers of Giabong, Pooh,
Nako, Tabo, Sagnam, Hurling, Lossar, Keylong,
Jahalma and Tuwan.

Community Support

Champions (Men) - Tanba Chhering, Prabhu
Daya, Padma Angchuk, Kham Raj, Dhoni Chand,
Devender Singh, Prem Chand, Debu, Ajay, Sonam
jeet, Raju, Nawang, KL Thakur, Kishan Kumar,
Tanzin Thinley, Kalzang Gurmet, Tanzin Thuktan,
Rinchen Tobge, Kesang Chunit, Tandup Chhering,
Namgial Bodh, Tanzin Tsewang, Tanzin Chhering,
Dorje Chhering, Dorje Bodh, Takpa Tanzin, Tanzin
Sherab.

Champions (Women) - Lobzang Yangchen,
Chhering Lanzom, Tenzin Chhoyyi, Tashi Chhomo,
Chhering Dolma, Dolma Zangmo, Tashi Dolma,
Chhering Chhodon, Tanzin Dolker, Chhering
Zangmo, Chhering Dolma

We would also like to emphasize the critical role
played by community members in each of the
locations where fieldwork was conducted. Some
of them also took part in analysis of the data. This
work would not have been possible without their
active participation and large hearted support.

We would like to thank the Snow Leopard Trust
for their guidance and support as our knowledge
partners. Finally, this work not have been possible
without the generous support of the Royal Enfield
Social Mission and the Snow Leopard Trust.

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Appendix

Snow Leopard Profiles



K1 - Left



K1 - Right



K2 - Left



K2 - Right



K4 - Cubs



K4



K5 - Left



K5 - Right



K6 - Left



K6 - Right



K7 - Left



K7 - Right



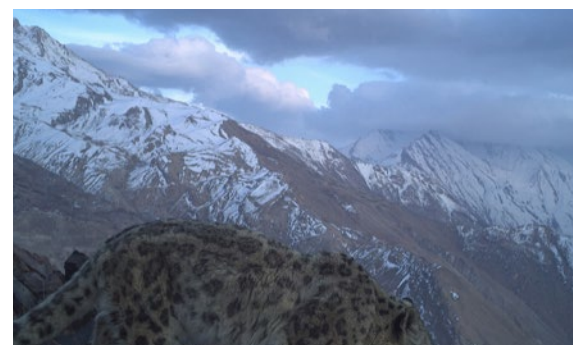
K8 - Left



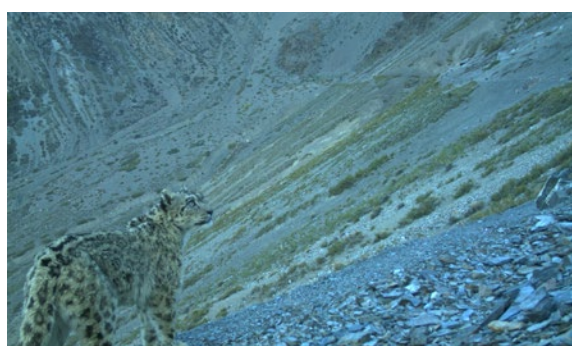
K8 - Right



K9 - Left



K9 - Right



K3



TB1



TB2 - Left



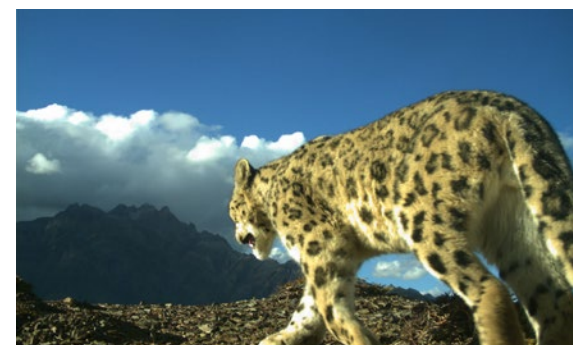
TB2 - Right



TB3 - Left



TB3 - Right



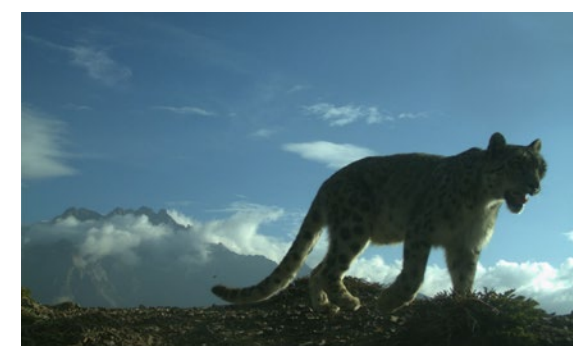
TB4 - Left



TB4 - Right



TB5 - Left



TB5 - Right



TB6 - Left



TB6 - Right



PIN1 - Left



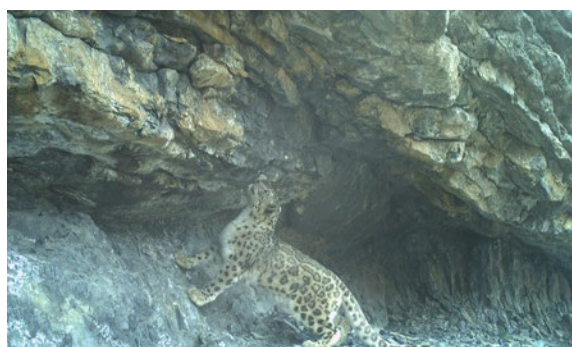
PIN1 - Right



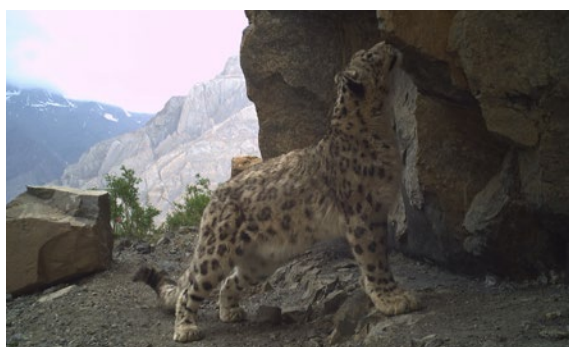
PIN2



PIN5



PIN3 - Left



PIN3 - Right



PIN4 - Left



PIN4 - Right



PIN6 - Left



PIN6 - Right



PIN7 - Left



PIN7 - Right



PIN8 - Left



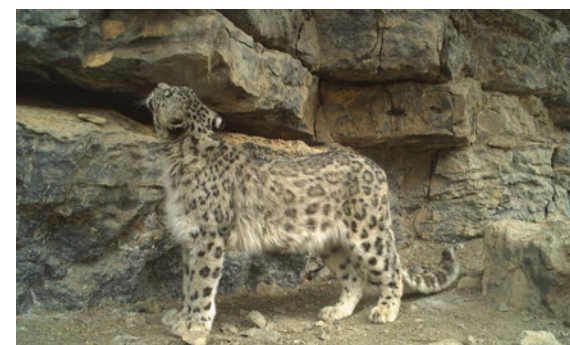
PIN8 - Right



USL1 - Left



USL1 - Right



USL2 - Left



USL2 - Right



USL3 - Left



USL3 - Right



USL4 - Left



USL4 - Right



USL5 - Left



USL5 - Right



USL6 - Left



USL6 - Right



USL7 - Left



USL7 - Right



USL8 - Left



USL8 - Right



USL9 - Left



USL9 - Right



USL10 - Left



USL10 - Right



USL11 - Left



USL11- Right



USL12 - Left



USL12 - Right



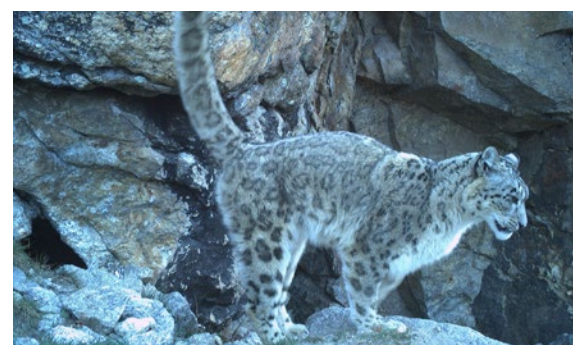
L1 - Left



L1 - Right



L2 - Left



L2 - Right



L3 - Left



L3 - Right



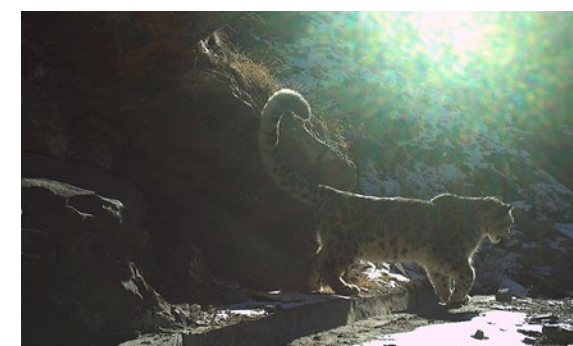
L4 - Left



L4 - Right



L5 - Left



L5 - Right



L6 - Left



L6 - Right



L7 - Left



L7 - Right



L8 - Left



L8 - Right



G1

Annexure

A blue - print of the phases/steps that are required when such a survey has to be repeated

Phase	YEAR 1												YEAR 2		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Planning	10														
Preparation	10														
Fieldwork			15-20												
Data analysis Tagging Snow Leopard IDing SECR analysis								4-6							
										7-8					
														1-2	
Writing														8-10	

The number of people involved in each phase are indicated on their respective bars.



Kaizang Gurnet

Details of snow leopard detections across the Protected Areas of Himachal Pradesh. Unique IDs correspond to snow leopard profiles provided in the appendix.

Name of PA	Number of camera traps deployed	No. of snow leopard detections	No. of individual snow leopards identified	Unique ID of snow leopard individuals
Pin Valley National Park	11	11	4	Pin1, Pin2, Pin4, Pin6
Kibber Wildlife Sanctuary	13	40	6	USL1, USL5, USL7, USL9, USL11, USL12
Sechu Tuan Nala Wildlife Sanctuary	6	3	1	L8
Great Himalayan National Park	16	1	1	G1
Sainj Wildlife Sanctuary	2	0	0	NA



Wildlife Wing - HPFD and NCF





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